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ANALYSIS OF SOUTHEAST ASIA UNDERWAY REPLENISHMENT OPERATIONS

Hubert B. Wilder, Jr., et al

Stanford Research Institute

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Naval Warfare Research Center
Final Report

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NAVAL ANALYSIS PROGRAMS (CODE 462)
OFFICE OF NAVAL RESEARCH
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13 ABSTRACT

The objectives of the research conducted were: (1) to validate the analytic procedures, specifically, the computer transfer simulation model and associated procedures, developed in the 1963 NWRC/SRI research entitled, "A Study of Systems for Replenishment of Naval Forces at Sea" (U) for their employment in the analysis of current and future underway replenishment operations; and (2) to identify the significant factors affecting the efficiency of replenishment at sea as it evolved in Southeast Asia operations.

Major conclusions are: (1) the NWRC/SRI Replenishment at Sea Computer Transfer Model simulates actual operations validly; (2) potentially, simulation of underway transfer could be used as an operational, planning, and training tool; (3) two factors dominate transfer rate: volume of cargo transferred and ship type; (4) vertical replenishment transfer rates are (a) improved by the use of two helicopters to a single receiving ship, and (b) within the ranges reported, appear to be sensitive to replenishment range only over large range increments.

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PREFACE

This volume is the final report of research conducted under the Office of Naval Research funded task "Analysis of Southeast Asia Underway Replenishment Operations " As originally conceived this research task consisted of three phases. The first two phases, Transfer Simulation Model Validation and Significant Factors Identification are reported herein. The third phase, a follow-on study to identify the impact of what was learned about Southeast Asia replenishment at sea operations on future underway replenishment, was not implemented. As a result, this report is essentially historical in nature and is restricted to an analysis of Unrep (underway replenishment) data collected by ComServPac (Commander Service Force Pacific Fleet) attendant to the support of operations at sea off Southeast Asia between December 1967 and April 1969. The reader is requested to bear in mind that the findings of this research are specific to those operations during that period. The nature of naval operations during that time in that theater of operations certainly affected the nature of underway replenishment operations. Further, many of the specific procedures and equipment characteristics typical of those operations may have been overcome by subsequent developments in the continuing programs conducted by the U.S. Navy to improve underway replenishment. However, differentiation between the operations analyzed and other underway replenishments elsewhere or in the future was beyond the assigned scope of this task.

The project was conducted under ONR research contract N00014-68-A-0243, Project 7590-217, administered by J. R. Marvin, and later by R. L. Miller, Director of Naval Analysis Programs, Office of Naval Research (Code 462), Arlington, Virginia. The work was conducted by the Naval

Warfare Research Center (NWRC) of SRI, L. J. Low, Director. The project leader was H. B. Wilder, Jr., Manager, Tactical Logistics and Mobility Program, NWRC. Members of the project team from the NWRC staff were W. L. Edwards, E. H. Means, R. B. Ringo, G. A. Miller, C. J. Fortier, and R. R. Newman. Professor Donald Guthrie served as consultant on statistical analysis. Professor F. R. McFadden, author of the original computer transfer model, participated as a consultant to the model validation process.

This final report supersedes the interim Précis Report of the same title, dated July 1971. Holders are requested to destroy the Précis Report as it is no longer the best source of information on these analyses.

I INTRODUCTION

A. Background

In 1964 the Naval Warfare Research Center and the Logistics Systems Group of Stanford Research Institute completed a program of systems analysis of replenishment at sea for the Office of Naval Research and the U. S. Navy Bureau of Ships. The time periods of that study emphasis were 1965-68 and 1972-75.* In the course of conducting that study, various analytic techniques were developed to examine the broad variety of replenishment at sea operations. Chief among these was a computer program that permitted simulation of the transfer process. Pursuant to the use of the model, a group of handling rates was developed for the future periods. These rates vary by product, ship class, and handling system. This model was not exercised subsequent to completion of the study.

By 1968 interest in the support of combat ships at sea was renewed and brought into focus as a result of the Southeast Asia conflict. Because changes had occurred in the interval since completion of the 1964 study and although many of these changes had been anticipated by that study, there was a need to examine their effect on the way replenishments were actually accomplished. For example, modified ship classes had joined the fleet. Some old replenishment equipment had been replaced

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* "A Study of Systems for Replenishment of Naval Forces at Sea" (U), Final Report, SECRET, SRI, Menlo Park, July 1963, and "Replenishment at Sea: Description of Transfer Model," (U), NWRC/LSR, Research Memorandum 26, UNCLASSIFIED, SRI, Menlo Park, March 1964, are the reports produced by the earlier research program that bear on the current research.

by improved gear. Techniques of replenishment had been improved. Probably one of the most significant changes that had occurred was not in the equipment field, but in the base of fleet operating experience. Southeast Asia logistic requirements had caused underway replenishment of significant volumes of ordnance to be the rule rather than the exception in contrast to the prevailing environment of training operations and token transfers that had served for the prior study. Moreover, frequency of replenishment at sea was much increased.

In the normal course of operational and supply system record keeping, a great deal of data were accumulating concerning underway replenishments, especially in Southeast Asia. These data required analysis to identify the salient features of the currently evolved systems for replenishment, and to determine the significant factors affecting the efficiency of these operations. The data also provided the opportunity to validate the existing Replenishment at Sea Transfer Model and to test its potential use in subsequent analyses of current and future underway replenishment operations. It was for these purposes, and in view of the previous work of the Stanford Research Institute team in underway replenishment, that the Operations Evaluation Group, Southeast Asia Combat Analysis Division, and the Office of Naval Research requested the Naval Warfare Research Center to undertake this study.

At the time the task was inaugurated the research team was fully committed to pressing prior assignments. However, changes to fleet operations in the Southeast Asian campaign impending in mid-1968 made it imperative that an experienced observer witness actual replenishments at sea before the "bombing standdown" to place in context subsequent analysis of data that had accumulated. This field trip was made in the fall of 1968, with subsequent analysis of data collected by ComServPac to follow at a later time. A cut-off date of April 1969 was established

for data to be processed, since neither funds nor time permitted additional visits to the Seventh Fleet for observation of operations. A series of other urgent demands on the time of the analysts has delayed publication of this report far later than its anticipated schedule. However, no similar effort of this scope appears to have been conducted in this subject area and its documentation, although late, should serve a useful purpose.

B. Objectives

The objectives of the research conducted were to:

(1) Validate the analytic procedures, specifically, the computer transfer simulation model and associated procedures, developed in the 1963 NWRC/SRI research entitled, "A Study of Systems for Replenishment of Naval Forces at Sea" (U) for their employment in the analysis of current and future underway replenishment operations, updating them as required.

(2) Identify the significant factors affecting the efficiency of replenishment at sea as it evolved in Southeast Asia operations.

C. Research Activity Recapitulation

The research effort was expended in three areas of activity: field trips, simulation of underway transfers, and statistical analysis of underway replenishments reported to Commander Service Force, U.S. Pacific Fleet (ComServPac).

1. Field Trips

Field trips included observation of replenishment at sea operations conducted in the waters off Vietnam (primarily in the vicinity of

Yankee Station) for approximately two weeks in August 1968, as well as several visits to ComServPac.

The observer, who had extensive prior experience in both underway replenishment operations and analysis, was based with CTG73.5 for the at-sea phases of this field trip. Representative combatant, as well as service force ships, were visited during replenishment operations. Extensive interviews were conducted with the host staff, Commander Service Squadron Three (who visited the fleet during this period), and officers and personnel of delivery and receiving ships. Various background information was collected in the process to put data from other operations not actually observed in proper perspective.

2. Simulation Validation

Computer simulation of underway transfers was made of three actual transfers to CVAs selected by the staff of ComServPac. In addition, another group of transfer cases was selected by the NWRC staff for simulation. All of these cases were limited to transfer of ordnance and ammunition since sufficiently detailed records of material transferred were available only in that broad commodity class.

The computer model operates through the use of a series of handling rates and area capacities at the various steps in the movement of products from origin on delivery ship to destination on receiving ship. These rates and capacities are a function of product (e.g., 5" 38 caliber projectile), ship type (e.g., AOE 1 Class), and equipment (e.g., Burton transfer rig). The principal modification made to the original factors projected for the 1968 era underway replenishment in the 1963 NWRC/SRI study was to update handling rates to reflect intervening changes in packaging of unit loads. For the cases selected by NWRC, rates for retrograde cargo were estimated and used in the simulation of those cases. Assignment of cargo to various transfer routes

was then made and the transfer was simulated using expected values, i.e., deterministic values, for the various steps in the transfer process. The transfer time produced by this simulation was compared with the transfer time reported to ComServPac for the actual operation. Additional analysis to examine the effect of improved rates at each state of transfer on overall transfer times was performed by increasing the original rate at each transfer stage in increments of 10%.

3. Statistical Analysis

The statistical analysis was performed on reports of underway replenishments made in accordance with ComServPac Instruction 3180.3F. The data analyzed covered underway replenishment operations conducted by the U.S. Pacific Fleet during the period December 1967 through April 1969. These reports are made for each underway replenishment by the delivery ship. They are divided into nine groups: surface transfer of ammunition, provisions, and stores; surface transfer of JP, NSFO, and aviation gasoline; and vertical (helicopter) transfer of ammunition, provisions, and stores. Each record contains about 20 elements of information that collectively identify and summarize the transfer operation. These data were received in punched card format from ComServPac. The first stage in the analysis was to verify the actual card records with the stated format, detect format errors, correct errors which could be corrected, and eliminate irreconcilable records. A computer routine was constructed to perform this screening. More than 15,000 records survived this test. Other checks indicated that the records are neither complete, i.e., do not contain reports of all transfers made, nor consistent, i.e., in some records reported estimated delay times have been subtracted from transfer or pumping times reported, in others the delay times are reported as part of transfer or pumping times. Other records were found to

contain obvious inaccuracies in numerical data reported, even though they survived the format test. Wherever possible these inaccurate records were screened out and discarded.

Another problem with the data was that the records do not contain sufficient information to permit unambiguous definition of the nature of simultaneous or multiple replenishments. As a result, analysis of the full effectiveness of the new multiproduct ships, AOE and AFS, is not complete. Despite its imperfections, however, the data base used represents a very large and useful sample of historical data for analysis of significant factors affecting the efficiency of replenishment at sea in Southeast Asia operations.

These data were divided into different categories (e.g., by delivery ship class, by receiving class, night, day, and so forth), and various statistical analyses were conducted on the resulting subpopulations. The principal tool in this analysis was the production by the computer of a quadratic regression plot of transfer rate versus volume transferred. The program performed the regression and recorded the data. It then plotted the data points as well as the regression curve directly on a cathode ray tube, and a photographic record of the plot was made.

Another facet of this analysis was a stepwise regression of selected CVA transfer records. Two dependent variables--Total Alongside Time Transfer Rate and Transfer Time Transfer Rate--were examined against up to 24 independent variables (e.g., Quantity Transferred, Logarithm of Quantity Transferred, Rig/Unrig Time, Number of Lifts, and so forth). This program cross correlated all 26 variables and then selected successively the independent variables in order of their contribution to the regression solution, recording the various data at each step. Similar analysis was performed for the vertical replenishment data. Except for one nonrecurring report on handling rates, no new reports from the fleet

were occasioned by this research project. Rather, the research proceeded through the use of reports already required for the administration and management of Service Force, Pacific Fleet, by ComServPac. Recapitulation of underway replenishments conducted is the subject of recurring reports issued by the Service Force and no attempt was made to duplicate these macrostatistics in this research.

During the early stages of the statistical analysis, LCDR C. D. Douglas, USN, was assigned to the study team for a summer experience tour from the U.S. Naval Postgraduate School. During this time he began work that resulted in his master's thesis, "Delay Analysis of Pacific Fleet Underway Replenishments" (U), USN Postgraduate School, April 1970. This work is excellent in quality and comprehensive in scope and by prior arrangement was not duplicated in the NWRC effort.

D. Report Organization

In this report, Chapter II presents the major conclusions of the research with a brief discussion of each finding. Chapter III reviews the validation of the NWRC/SRI Replenishment at Sea Computer Transfer Model simulation of actual transfers. Chapter IV contains the discussions of the various analyses conducted to identify significant factors affecting the efficiency of replenishment at sea as it evolved in the Southeast Asia operations. Chapter IV is organized by the three general categories of ComServPac symbol 3180/1 reports: Dry Cargo Connected Transfers, Fuel Transfers, and Vertical Replenishments. Because of the volume of data underlying the analysis in Chapter IV, only those quadratic regression plots that directly illustrate the results of final stages of the analysis are presented in the chapter itself. The other quadratic regression plots, which were used in earlier stages of the analysis, are presented in the Appendix.

II MAJOR CONCLUSIONS

A. <u>The NWRC/SRI Replenishment at Sea Computer Transfer Model simulates actual operations validly.</u>

For example, on 8 June 1968 AOE 1 transferred 505 tons of ordnance/ammunition to CVAN 65 in 3 hours, 17 minutes reported actual time. Simulation time was 2 hours, 57 minutes. On 28 May 1968 AE 25 transferred 543 tons of ordnance/ammunition to CVA 63 in 3 hours, 59 minutes reported actual time. Simulation time was 3 hours, 47 minutes. Other examples are reported in Chapter III.

B. <u>Potentially, simulation of underway transfer could be used as an operational, planning, and training tool.</u>

1. For the cases simulated, the computer simulation produced a much more accurate prediction of transfer time than either the simplistic tons per hour approach or the more complex regression analysis. One explanation is that the mix of products transferred is a major factor in determining transfer time.

2. Simulation offers a quick method of detecting bottlenecks. In the examples given in conclusion A, further analysis of the transfers by simulating improved stages of transfer indicates that improved transfer times were dependent on improved receiving ship conditions in the AOE 1-CVAN 65 case; the AE 25-CVA 63 case, conversely, required improved delivery ship conditions.

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3. Simulation may offer a device for training purposes. For example, data collected during an actual training underway replenishment of only token amounts of cargo might be introduced to the simulation model to estimate performance during a full replenishment. The stepwise regression analysis, for example, indicates there is a statistically significant relationship between rig and unrig time and total transfer rate even though the rig-unrig times are a minor fraction of total transfer time. More extensive analysis than was within the scope of this work might develop such predictors for this use.

C. <u>Two factors dominate transfer rate: volume of cargo transferred and ship type; but neither of these is a valid predictor of transfer rate.</u>

1. The predominant characteristic of the ComServPac 3080/1 data is the wide variability in transfer rates, whether based on total alongside time or transfer time. Undoubtedly, part of this variation is a result of errors either in the original report or in subsequent keypunch transcription. However, even when sets of the data were hand screened to eliminate apparent errors and "outliers," the rates are still characterized by great variation for a given subpopulation or sort by parameter.

2. Of all the different factors examined, the single most dominating effect on transfer rate was volume of cargo transferred. While some low volume transfers were achieved at high rates and some high volume transfers

occurred at relatively low rates, the pattern of higher volume equals higher rate was consistent for all product types, all ship classes, and all transfer methods. Obviously, at some point this improvement in transfer rate levels off. The relatively low coefficient of correlation obtained in some cases verifies the noncontinuous linearity of the data. However, the data suggest that most of the underway replenishments were conducted at volumes under this point.

3. The vast majority of transfer (83%) used either four or five rigs. Consequently, the observed pattern of higher volume resulting in a higher transfer rate was not a discernible function of the number of rigs used in making the transfer. Although the number of rigs could logically be expected to influence transfer rate, the low correlation between these factors indicated that the influence was minor.

4. The general applicability of the effect of volume transferred on transfer rates was corroborated by a comparison of transfer rates reported for ServPac ships in 1964 with rates for the same ships in 1968. Transfer rates for ordnance and ammunition increased in 1968 about proportionately to the increased volumes transferred per replenishment. Similarly, the provisions, stores, and fuel transfer rates for the later period actually declined from the 1964 rates approximately the same as the volumes transferred per replenishment.

Certainly other factors contributed to the observed decline in provisions, stores, and fuel transfer rates. Receiving ship command emphasis, for example, probably concentrated on achieving high provision transfer rates in 1964 when replenishment of that cargo was the chief means of demonstrating dry cargo underway replenishment efficiency. In 1968 ammunition transfer times usually predominated periods allotted to combat ships for replenishment and so those transfers probably received more emphasis than the provisions transfers, which were not only smaller in volume but more frequently scheduled than during peacetime.

5. The effect of volume transferred on transfer rate has implications to the scheduling of underway replenishments. The effect should be reflected in planning factors for operational or study use. It also complicates the evaluation of training operations where only token transfers are made. There is a strong suggestion that underway replenishment standards of excellence should reflect this effect.

6. The next most influential factor affecting transfer rate was ship type. This would be expected since ship type characterizes the type of transfer methods and handling facilities available, the type of cargo to be transferred (e.g., bombs to CVA, 5" 38 caliber projectiles to DD) and generally, within broad limits, for receiving ships the volume of cargo usually transferred.

7. While data aggregated for all transfers of a product class indicate that ordnance is transferred at slightly lower rates than provisions or stores, this condition does not always obtain for transfers to individual classes of ships. For example, aircraft carriers (CVA, CVAN, CVS) received ordnance at an average rate of about 144 tons/hr, provisions at an average rate of 84 tons/hr, and stores at an average rate of 63 tons/hr.

8. The following discussion on delivery ships and receiving ships is a result of a detailed statistical analysis of recorded transfers to CVs via connected rigs.

a. Delivery Ships

(1) Ordnance (AE, AOE): Although some differences in average transfer rates for the different ordnance occur (140.1 tons/hr to 154.6 tons/hr) for AOE and AE classes, these differences do not pass tests for statistical significance, i.e., tests of the constituent records indicate the observed differences in averages could occur in samples taken from the same population. Therefore, transfer rates among the ship classes for this product taken separately are about the same.

(2) Provisions (AF, AFS, AOE): Mean transfer time transfer rate for AF was 91.5 tons/hr, for AFS 75.6 tons/hr, and for AOE 37.8 tons/hr. All differences are statistically significant at the 1% level.

(3) Stores (AFS, AKS): AFS and AKS transfer rates (56.2 tons/hr and 71 tons/hr), although ostensibly quite different, do not pass tests for statistical significance, and transfer rate for this product taken separately therefore was about the same for these ship types. Insufficient AOE stores transfers were recorded to include in the test

(4) Fuel (AO, AOE): Mean pumping rate to CV for AO 105 class was 7352 barrels/hr, for AO 143 class 6552 barrels/hr, AOE 1 class 5817 barrels/hr, and AO 22 class 5110 barrels/hr. All of these differences in mean pumping rate are statiscally significant at the 1% level. On the basis of pumping rate per hose used, this same order of transfer rates prevails. However, the difference between AOE rate per hose and those of the adjacent classes (AO 143 and AO 22) are not statistically significant.

b. Receiving Ships

(1) Ordnance: CVA classes and the CVAN received ordnance at mean rates ranging from 154 tons/hr to 131.6 tons/hr (with CVAN 65 lowest), but the calculated differences in receiving rates do not pass tests for statistical significance. Ordnance receiving rate for all CVA classes (average 148 tons/hr) was found to be statistically significantly different from the CVS average of 121.6 tons/hr.

(2) Fuel: Overall average pumping rate (to all CV) for NSFO was 5718.3 barrels/hr and for JP 6233.8 barrels/hr, a significant difference. However, NSFO rates to CVA were almost identical to JP rates to CVA (6285.9 and 6246.8 barrels/hr, respectively). NSFO rates to CVA were significantly greater than similar transfers to CVS (4742.8 barrles/hr), as were JP transfers (4687.6 barrels/hr to CVS). Conversely, JP transfer rates to CVA were not significantly different from JP transfers to the CVAN (6727 barrels/hr). Average quantities pumped suggest one explanation for the differences in CVA/CVAN and CVS pumping rates in that the average JP transfer to CVA/CVAN was 10,502 barrels and to CVS only 5357 barrels (means significant at 1% level).

D. <u>Although factors other than volume transferred and ship type were identified as having some effect on connected transfer rates, none of these other factors taken singly or in combination appears to have had a major effect.</u>

1. In the case of ordnance transfers to aircraft carriers, Total Alongside Transfer Rates reflected a statistically significant (at the 1% level) positive effect (i.e., effect tending to increase transfer rates) of transfers made in WestPac versus EastPac transfers, and negative effects of simultaneous operations and of increased delay times. When Quantity Transferred and Total Alongside Transfer Time were eliminated as explanatory variables, thereby increasing the relative power of the other explanatory variables, rig and unrig time was also identified as having a significant negative effect at the 1% level. The effects of these factors were small compared with the effect of Quantity Transferred.

   Transfer Time Transfer Rates, (i.e., Transfer Rates computed on the basis of Transfer Time) for ordnance transfers to aircraft carriers showed no significant dependence on any of these other factors until Quantity Transferred and Transfer Time were eliminated as explanatory variables. When this was done, a significant (at the 1% level) positive effect of WestPac versus EastPac transfers, and negative effect of increased rig and unrig times, were identified. In addition, nighttime transfers were found to have a significant negative effect at the 5% level. The effects of these factors were small compared with the effect of Quantity Transferred.

2. No discernible pattern of transfer rate could be detected as a function of how long the ship had been deployed to WestPac, how long it had been on the replenishment line (i.e., at sea during a period), or even frequency of replenishments during a period. Two explanations are suggested for this. First, it is quite probable that by late 1967 the general state of training in underway replenishment was sufficiently high to eliminate the expected "learning curve" effect of improvement during a given deployment. Second, although there were differences in work loads of replenishment ships from time to time, the scheduling procedures followed by the CTF 73 representative at sea in Southeast Asian waters probably prevented saturation of an underway replenishment ship to the point of observable declining transfer efficiency.

E. Vertical replenishment rates were improved about 20% overall by the use of two helicopters to a single receiving ship with increasing improvement occurring as replenishment range increased.

For all ranges, vertical replenishments to non-CV receiving ships averaged 13.62 tons/hr for one helicopter and 16.46 tons/hr for two helicopters (difference significant at 1% level). Between 101 and 1000 yards (i.e., close-in but not alongside) one-helicopter rates averaged 14.66 tons/hr and two-helicopter rates averaged 18.2 tons/hr (difference significant at 1% level). At 5001 to 6000 yard ranges one-helicopter rates averaged 6.9 tons/hr and two-helicopter deliveries averaged 14.2 tons/hr (differences significant at 5% level).

F. <u>Vertical replenishment rates decrease with replenishment range, but only in broad increments of distance.</u>

Overall average for vertical replenishments to non-CVA receiving ships was 14.4 tons/hr. When vertical replenishments to ships alongside were eliminated, the overall vertical replenishment average was 13.94 tons/hr. For 101 to 1000 yards the average was 15.7 tons/hr. From 1001 to 5000 yards average transfer rate was about 12.5 tons/hr for each of the 1000 yard increments. At 6000 yards and beyond, vertical replenishment rates decline to about 8.8 to 8.3 tons/hr. The highest transfer rate recorded for replenishment ranges greater than 1000 yards was 39 tons/hr at a range of 14,000 yards.

G. <u>Of the reported delays to completion of transfer, the predominant cause of the prolongment of alongside time was return of "empty brass".</u>*

1. About 40% of all delays reported by ships delivering solid cargo alongside were attendant to the return of "empty brass" (shell casings, aviation ordnance containers, and so forth). This category of prolonged alongside time accounted for more than 50% of all delay time reported in dry cargo connected transfers and added about 10% more total time to the transfer operation.

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* Analysis supporting this conclusion appears in LCDR C. D. Douglas, USN, "Delay Analysis of Pacific Fleet Underway Replenishment" (U), USN Postgraduate School Master's Thesis, April 1970.

2. About 21% of all delays reported by ships delivering POL cargo were attendant to the return of "empty brass," accounting for about one-third of all delay time reported and extending total transfer time about 5%.

3. During the Seventh Fleet field trip it was evident that no provision for the handling and storage of empty containers had been planned into any of the underway replenishment ships, including the most recent to join the fleet. Each ship "jury rigged" for the retrograde. Yet trends, especially in the containerization of sophisticated weapons, indicate this activity will continue and possibly increase in the future.

4. Delay in net return was the major prolongment reported in vertical replenishment, accounting for about 40% of all vertical replenishment delays reported both in frequency and time. Total time spent in vertical replenishment was extended about 7.5% by this delay alone.

III SIMULATION MODEL VALIDATION

The first objective of this research project was to validate the NWRC/SRI Replenishment at Sea Computer Transfer Model.* This simulation model was developed as part of a program of systems analysis of replenishment at sea completed by SRI in 1964, and it had not been exercised subsequently.

The simulation model operates through use of a series of handling rates and area capacities at the different steps in the movement of products from their origin on a delivery ship to their destination on a receiving ship. The rates and capacities are functions of product, ship type, and equipment. Products are identified in considerable detail, e.g., separate handling rates have been established for items such as 5" 38 caliber projectiles and 6" 47 caliber projectiles. Ship types are actually defined to the class level, e.g., AOE 1 class. Equipment is identified by the numbers and types of transfer equipment, e.g., Burton transfer rig. Rates and capacities projected for 1968 by the 1963 SRI/NWRC replenishment at sea study† were used, handling rates were updated to reflect intervening changes in packaging of unit loads.

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* "Replenishment at Sea: Description of Transfer Model" (U), NWRC/LSR, Research Memorandum 26, UNCLASSIFIED, SRI, Menlo Park, March 1964.

† "A Study of Systems for Replenishment of Naval Forces at Sea" (U), Final Report, SECRET, SRI, Menlo Park, July 1963.

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Validation of the simulation model entailed comparing results of actual replenishments with corresponding simulated transfers. The simulated transfers were structured to reproduce the actual transfers as closely as possible. There were two sources of data for specifying inputs to the simulation: ServPac report 3080, also used in the statistical analysis of Chapter IV; and ServPac report 8015-1, ammunition transaction reports, used primarily to maintain Pacific Fleet ammunition inventory control.

Two principal factors limited the number of transfers that were simulated. First, ServPac 8015-1 data overlapped 3080 data for April through November 1968 only. Matching of records from the two sources was difficult because analysts had to conduct detailed investigations of the frequent inconsistencies between them. Second, neither of the two reports provided a complete description of the parameters of the actual transfer. The 8015-1 data provided detailed information on items of ordnance, but no similar information on stores or provisions was available. The 3080 data provided the numbers and types of rigs used, and the numbers of lifts made by each type. Neither source specified what each lift consisted of, nor were movement paths described. It was therefore necessary for analysts to manually assign movement paths to the various packages and to approximately balance rig operations.

Working within these two constraints, 16 actual transfers, representing a variety of delivery and receiving ship types, were selected and simulated. The transfer times of the simulated and actual transfers, including time required for return of retrograde brass to the delivery ship, were computed. They are listed in Table 1. Delays resulting from causes other than retrograde brass transfer are not included in transfer time.

Table 1

RESULTS OF REPLENISHMENT SIMULATIONS VERSUS REPORTED RESULTS

Delivery Ship	Receiving Ship	Date	Transfer Time (minutes)			Differences, as Percent of Reported Time, of Simulated from	
			Simulated Time	Reported Time	Uncertainty Range of Reported Time	Reported Time	Uncertainty Range Limit
AE 5	DD 882	4 Sep 68	65	62	57-67	4.84	0
AE 5	DD 875	3 Sep 68	59	95	90-100	-37.89	-32.63
AE 15	DDG 24	26 Sep 68	28	34	29-39	-17.65	-3.94
AE 15	DD 499	4 Sep 68	26	23	18-28	13.04	0
AE 15	CVA 66	2 Sep 68	238	208	203-213	14.42	12.02
AE 18	DD 885	23 May 68	73	73	68-78	0	0
AE 18	DD 566	27 Jul 68	49	48	43-53	2.08	0
AE 18	DD 946	27 Jul 68	92	86	81-91	6.98	1.10
AE 18	CVA 31	27 Jun 68	104	132	127-137	-24.24	-20.45
AE 25	DDG 21	25 May 68	45	28	23-33	60.71	42.86
AE 25	CLG 6	25 May 68	55	53	48-58	3.77	0
AE 25	DDG 14	11 Jul 68	14	10	5-15	40.00	0
AE 25	CVA 63	26 May 68	239	227	222-232	5.29	3.02
AOE 1	CAG 1	9 Jun 68	201	220	215-225	-8.64	-6.36
AOE 1	CVAN 65	8 Jun 68	177	197	192-202	-10.15	-7.81
AOE 2	DD 719	10 Jul 68	98	95	90-100	3.16	0

It is important to note that the percentage differences between actual and simulated times shown in Table 1 may be somewhat misleading as measures of the validity of the simulation. The transfer times reported from actual transfers may not be the true transfer times; delay times are reported in multiples of ten minutes, hence the reported times are accurate only within plus or minus five minutes, or in the case of multiple delays even more. Denoting five minutes above or below the reported transfer time as an uncertainty range, one should measure percentage differences between simulated and actual times only as they lie beyond the limits of the uncertainty range.

Figure 1 shows the results of the 16 cases, plotting percentage deviation of time computed by simulation from the reported transfer time as a function of reported time. The lines denoted "0" represent the uncertainty range, which decreases in width as reported transfer time increases. The lines labeled "5%" and "10%", respectively, delineate the points lying 5% and 10% (of the reported time) beyond the uncertainty range.

Examination of Figure 1 reveals that seven out of the 16 cases fall within the uncertainty range. Ten of the points fall within the 5% limits, and 12 within the 10% limits. It therefore appears that simulation is a reasonably valid method of predicting actual transfer times.

Further evidence of the validity of the simulation as applied to these 16 cases is seen in Figures 2 and 3--scatter diagrams of transfer rate versus simulated and reported times respectively. Notice that the two least squares quadratic fits yield regression curves of very nearly the same shape, and that the scatter of points is very similar in the two figures.

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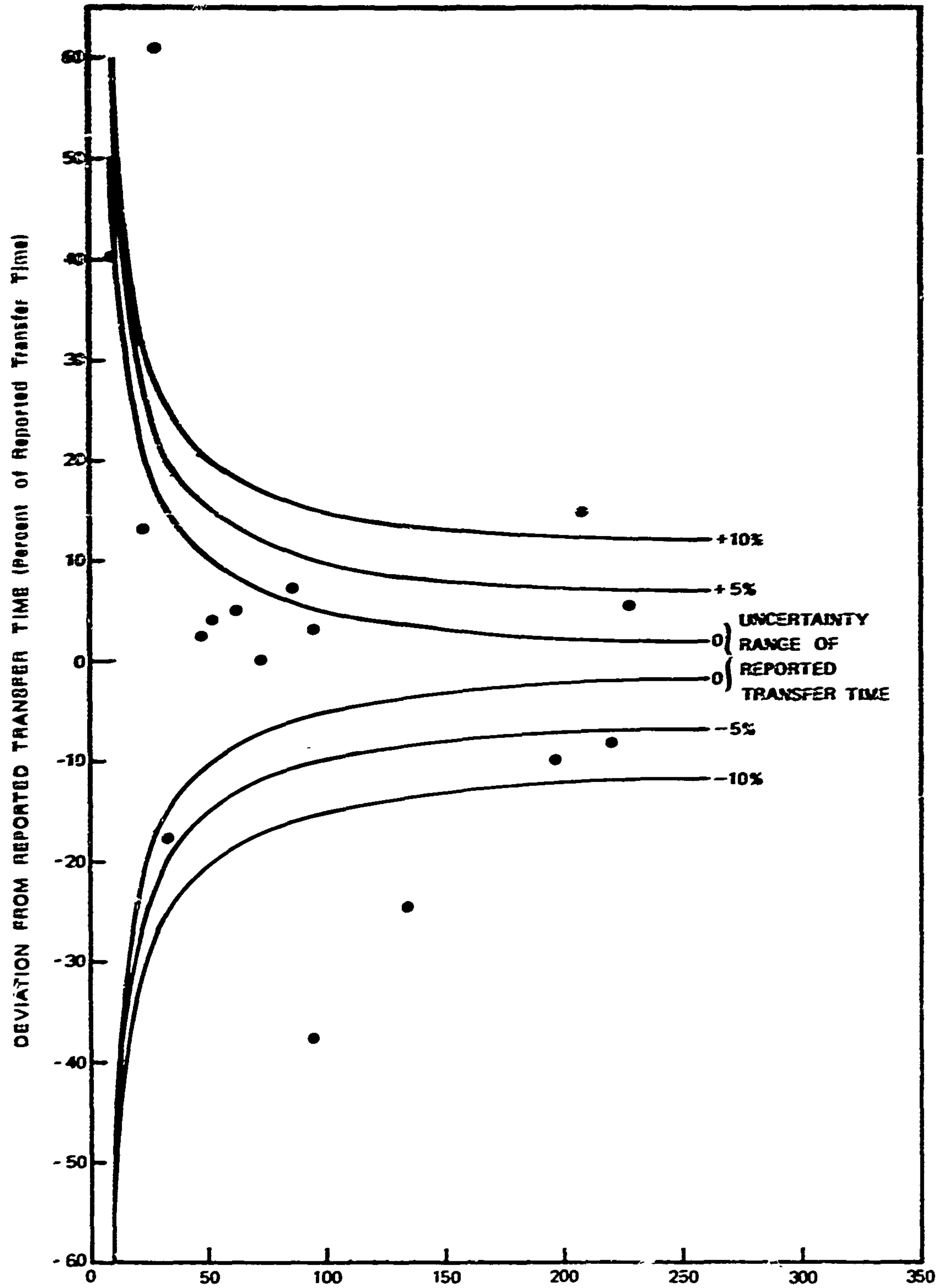

FIGURE 1 RESULTS OF SIMULATION CASES COMPARED TO REPORTED RESULTS OF ACTUAL REPLENISHMENTS

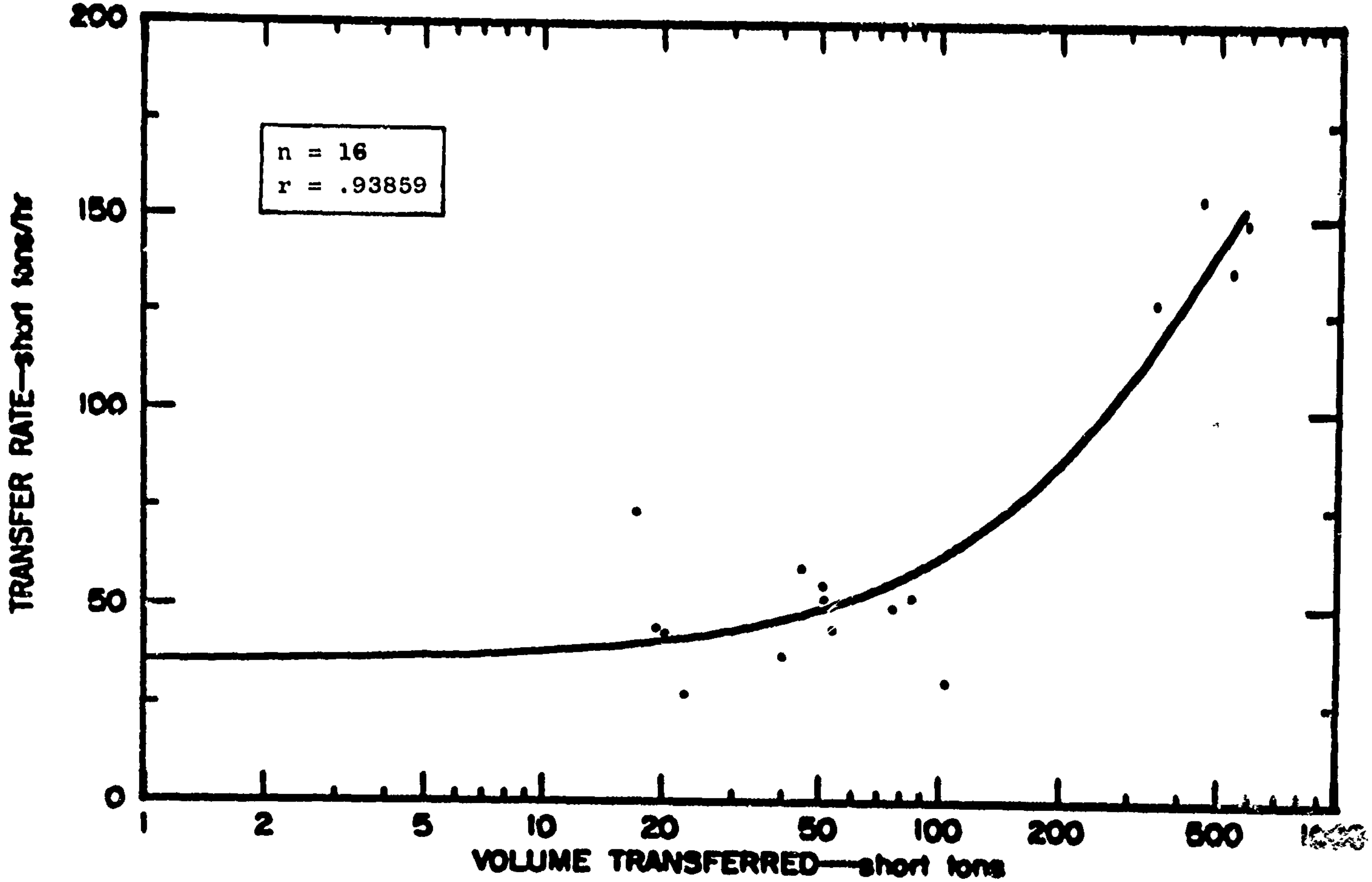

Figure 2 SIMULATED TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR REPLENISHMENTS INCLUDED IN SIMULATION VALIDATION PROCESS

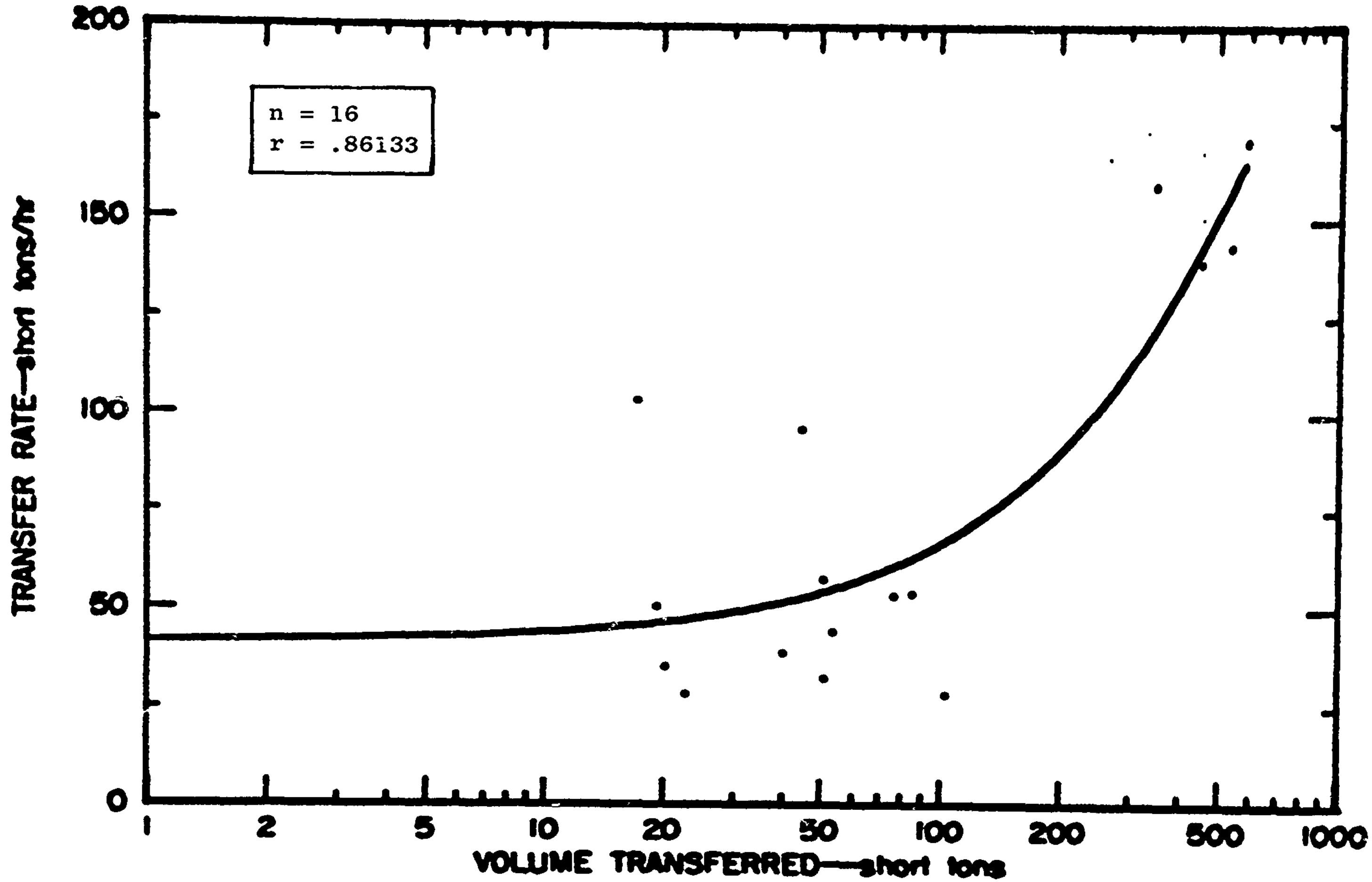

Figure 3 REPORTED TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR REPLENISHMENTS INCLUDED IN SIMULATION VALIDATION PROCESS

The validity of the simulation model makes it potentially useful as an operations, planning, and training tool. Its ability to predict transfer time is better than either the simplistic tons per hour approach or the more complex regression analysis. One explanation is that the mix of products transferred is a major factor in determining transfer time.

Simulation also offers a quick method of detecting bottlenecks. In the cases simulated, further analysis of the transfers by simulating improved stages of transfer indicates that improved transfer times were dependent on improved receiving ship conditions in the AOE 1-CVAN 65 case; the AE 25-CVA 63 case, conversely, required improved delivery ship conditions.

Simulation may also offer a device for training purposes. For example, data collected during a training underway replenishment of only token amounts of cargo might be introduced to the simulation model to estimate performance during a full replenishment. A stepwise regression analysis, for example, indicated there is a statistically significant relationship between rig and unrig time and total transfer rate even though the rig/unrig times are a minor fraction of total transfer time. More extensive analysis than was within the scope of this work might develop such predictors for this use.

Another training application of the simulation model might be in training transfer ship officers in scheduling transfers. The sensitivity of the model to distribution of cargo among rigs could rapidly show officer trainees the effects of different scheduling methods, and provide them with insights that would increase their future efficiency.

IV EFFECTIVENESS FACTORS INVESTIGATION

A. General

The data in the ServPac 3080 reports reflected the phenomenon that the transfer rate attained in a given replenishment appeared to be highly correlated with the quantity of material transferred. The phenomenon appeared in connected transfers of both wet and dry commodities and in vertical replenishments. The appearance of this phenomenon suggested that analysis would be facilitated if scatter diagrams of transfer rate versus quantity transferred were prepared and empirical curves were fitted to the data. Accordingly, a computer program was written that permitted extraction of any desired subset of the data; plotting of the subset of data on a scatter diagram; computation of a second-degree, least squares curve and its associated statistics; and plotting of this empirical curve.

To determine whether the increase in transfer rate with quantity transferred could possibly result from the use of more rigs when larger quantities were transferred, the following correlations were made with the indicated results:

(1) Correlation between quantity transferred and number of rigs was 0.215. While this correlation coefficient differs at the 1% significance level from zero, thereby indicating that a positive correlation does exist, it is too small to be of any explanatory value.*

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* This low correlation was apparently caused, in part, by the high frequency (82.6% of the transfers) of use of either four or five rigs per transfer.

(2) Correlation between transfer time transfer rate and number of rigs was 0.065, which does not differ significantly from zero. Thus no correlation could be determined between these factors.

The next step was to determine which subsets of data constituted logical groupings for analysis. It was initially decided to consider connected transfers of dry commodities, connected transfers of fuels and vertical replenishments separately.

Analysis of the scatter diagrams for each of these groupings showed that transfer rate is correlated with quantity transferred. However, in no case was the empirical curve a very close fit to the data, even though it was the best possible second degree fit. This looseness of fit dictated an investigation of other factors that might bear on replenishment effectiveness. Investigations of possible effectiveness factors for each of the major groupings of replenishments are described in subsequent sections.

B. Connected Transfers of Dry Commodities

Connected transfers of dry commodities were further subdivided into ordnance, provisions, and stores transfers. Scatter diagrams were prepared for each of these commodity groups, and empirical curves were fitted. The empirical fits for individual commodity groups were better than the fit for all dry connected transfers, but still not sufficiently close to be adequately explanatory.

Transfers in which the receiving ships were CVA, CVAN, and CVS were selected for more detailed analysis. Scatter diagrams and empirical curves were prepared for all connected transfers of dry commodities and for transfers of each commodity group to this group of ship types. Each curve fit was an improvement over the corresponding curve fit for all receiving ship types. Also, fits for individual commodity groups

were better than the fit for all connected transfers. Again, however, the fits were not sufficiently good to be adquately explanatory.

Next, each commodity group was individually analyzed to determine whether transfer effectiveness, measured by transfer time transfer rate, varied among different delivery ship types or classes or among different receiving ship types of classes within the group of receiving ship types already selected. This analysis led to identification of homogeneous subdivisions of delivery and receiving ship types. Scatter diagrams were prepared for these subdivisions, and empirical curves were fitted. Additional detailed analysis was made of the ordnance transfers; this will be described in the ordnance subsection below.

Differences among delivery and receiving ship types and classes were analyzed by seeking statistically significant differences between the average transfer time transfer rates of the different types and classes. Because of the statistical nature of the data, it could not be known positively whether the existence of differences in the observed average rates for the different categories meant that the categories actually had different mean rates. Following standard statistical practice, one of the following statements could be made about such differences:

(1) If differences as great as those observed between averages would be expected to occur less than 5% of the time, given that the mean category rates were not actually different, the mean category rates were adjudged different at the 5% significance level.

(2) If the observed differences were so large that they would be expected to occur less than 1% of the time, again given that the mean category rates were not actually different, the mean category rates were adjudged different at the 1% significance level.

(3) If the observed differences were sufficiently small so that they would be expected to occur more than 5% of the time, given that the mean category rates were not actually different, the mean category rates were adjudged equal.

The following subsections will discuss ordnance, provisions, and stores transfers, respectively. In each subsection, the effects on replenishment effectiveness of delivery ship type and class, receiving ship type and class, quantity transferred, and other factors will be discussed.

1. Ordnance

a. Delivery Ship Type and Class

Average ordnance transfer time transfer rates to CVs from different delivery ship types and classes are given in the following tabulation, with the standard deviation of transfer rate and the number of observations.

Delivery Ship Type	Average Transfer Time Transfer Rate (tons/hr)	Standard Deviation of Transfer Time Transfer Rate (tons/hr)	Number of Observations
AE 3	142.81	56.35	272
AE 21	154.61	62.34	61
AE 26	140.18	43.25	55
All AE Classes	144.29	55.75	388
AOE 1	125.64	56.03	40
AOE 2	151.67	57.52	104
Both AOE	144.44	58.10	144

Using analyses of variances and tests of differences between the means, significant differences in ordnance transfer rates were sought and results were found as follows:

(1) Between AE as a single type and AOE as a single type, no significant difference was found. Hence, it was concluded that the delivery ship type does not affect ordnance transfer rate.

(2) Among all five classes of both AE and AOE (AOE1 and AOE2 were treated as separate classes for this analysis), no significant differences were found. Hence, it was concluded that the delivery ship class does not affect ordnance transfer rate when both AE and AOE classes are considered.

(3) Among the three classes of AE, no significant differences could be found. Hence, it was concluded that the class of AE does not affect the ordnance transfer rate from AEs.

(4) Between AOE1 and AOE2, a significant difference was found at the 5% level. It was therefore concluded that AOE2 did perform better in terms of the rate of transferring ordnance to CVs than did AOE1. The reason for this performance difference could not be determined from the data.

b. Receiving Ship Type and Class

Average ordnance transfer time transfer rates from AE and AOE to the CVA type, the CVAN type, and the CVS type are given in the tabulation below, with the standard deviation of the transfer rate and the number of observations.

Receiving Ship Type	Average Transfer Time Transfer Rate (tons/hr)	Standard Deviation of Transfer Time Transfer Rate (tons/hr)	Number of Observations
CVA	148.05	55.73	441
CVAN	131.60	47.72	43
CVS	121.62	62.87	48

No significant difference was found between CVA and CVAN transfer rates or between CVAN and CVS rates. However, the CVS was significantly slower at the 1% level in receiving ordnance than was the CVA.

Within the CVA type, no significant differences in transfer rates among classes were found. Observed average transfer rates for the CVA classes were as shown in the following tabulation.

CVA Class	Average Transfer Time Transfer Rate (tons/hr)
14	143.24
43	143.26
59	150.74
63	153.99

c. Quantity Transferred

The results described above suggest that the effect on transfer rate of quantity of ordnance transferred be subdivided as follows:

(1) Ordnance transferred to CVA and CVAN from AE and AOE.

(2) Ordnance transfers to CVS from AE and AOE.

Separate analysis of the effect of quantity on transfers from AOE1 and AOE2 did not appear justified in view of the dispersion in the data.

Plots of ordnance transfers from AE and AOE to CVA and CVAN and to CVS are presented as Figures 4 and 5, respectively.* The parameters and correlation coefficients of the second-degree, least squares curves are shown in the following tabulation:

	Curve Parameters			
Receiving Class	Intercept	Coefficient of Quantity Transferred	Coefficient of Square of Quantity Transferred	Correlation Coefficient
CVA, CVAN	2.6059	0.3839	-0.0003	0.70
CVS	1.1304	0.8828	-0.0019	0.77

The low correlation coefficients† indicate that the empirical curves do not provide a good fit to the data. This may be confirmed visually by observing Figures 4 and 5. Therefore, it was concluded that use of the least squares empirical curves to predict transfer rate based on quantity transferred is not justified, even when these curves are particular to homogeneous performance groupings of delivery and receiving ship types.

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* The quadratic regression plots of transfer rate versus volume that appear in this chapter are only those that directly illustrate the results of the final stages of analysis. The remainder of the plots, used in earlier stages of the analysis, appear in the Appendix.

† Statistical significance of the correlation coefficient is often a misleading criterion for evaluating predictability. The correlation r between two measurements X and Y indicates that 100 r^2 % of the variance of Y is "explained by" its association with X. $\sqrt{1-r^2}$ gives the amount of Y--dispersion remaining after allowing for linear dependence on X. Thus if $r = 0.70$, $\sqrt{1-r^2} = 0.71$; i.e., 71% as much dispersion in Y remains after adjusting for X as was present without considering X. The numerical value of $\sqrt{1-r^2}$ is therefore a more suitable measure of goodness of a model to be used for prediction purposes. (Continued on page 40.)

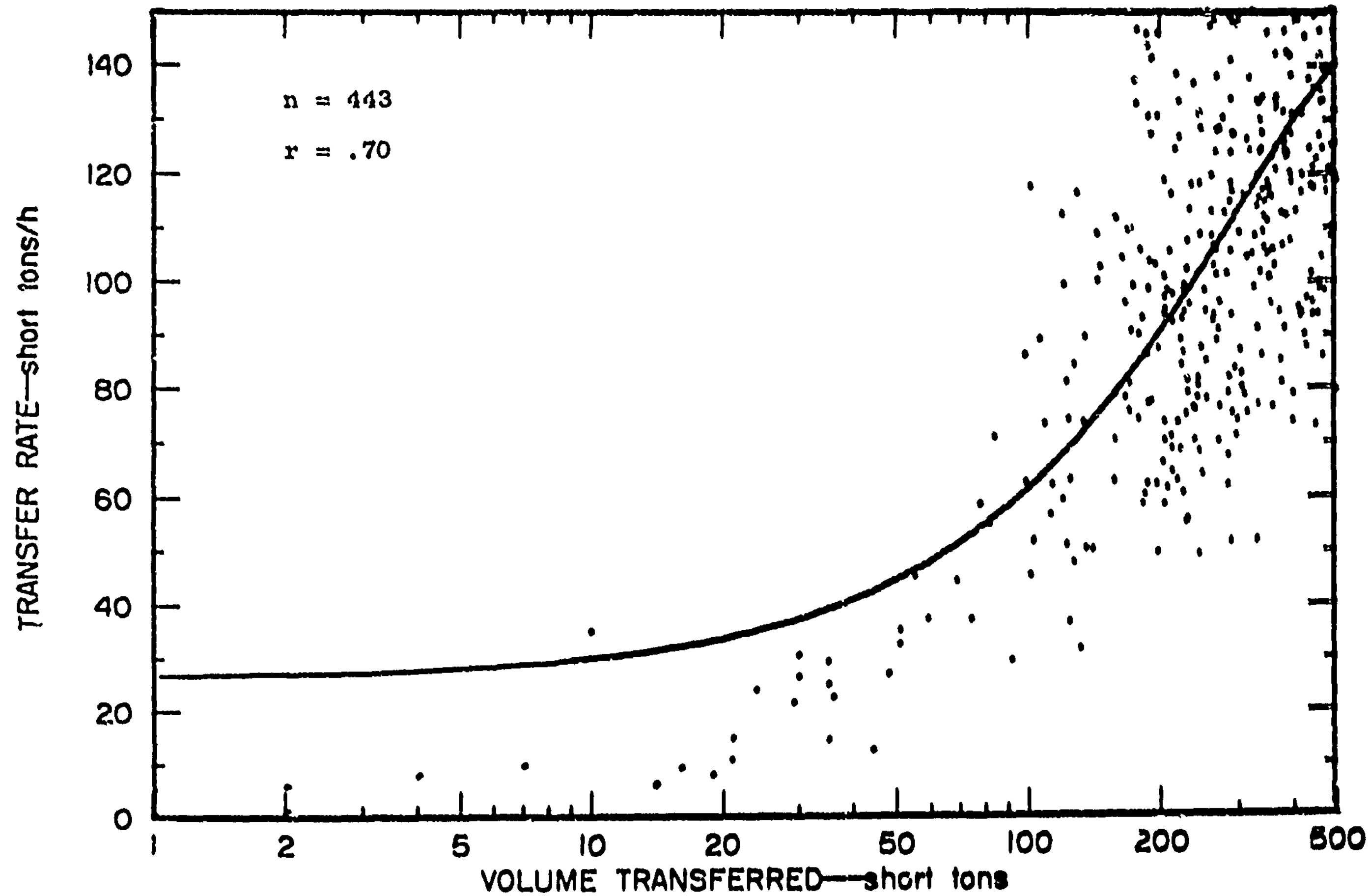

Figure 4 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVA AND CVAN TYPES BY AE AND AOE TYPES

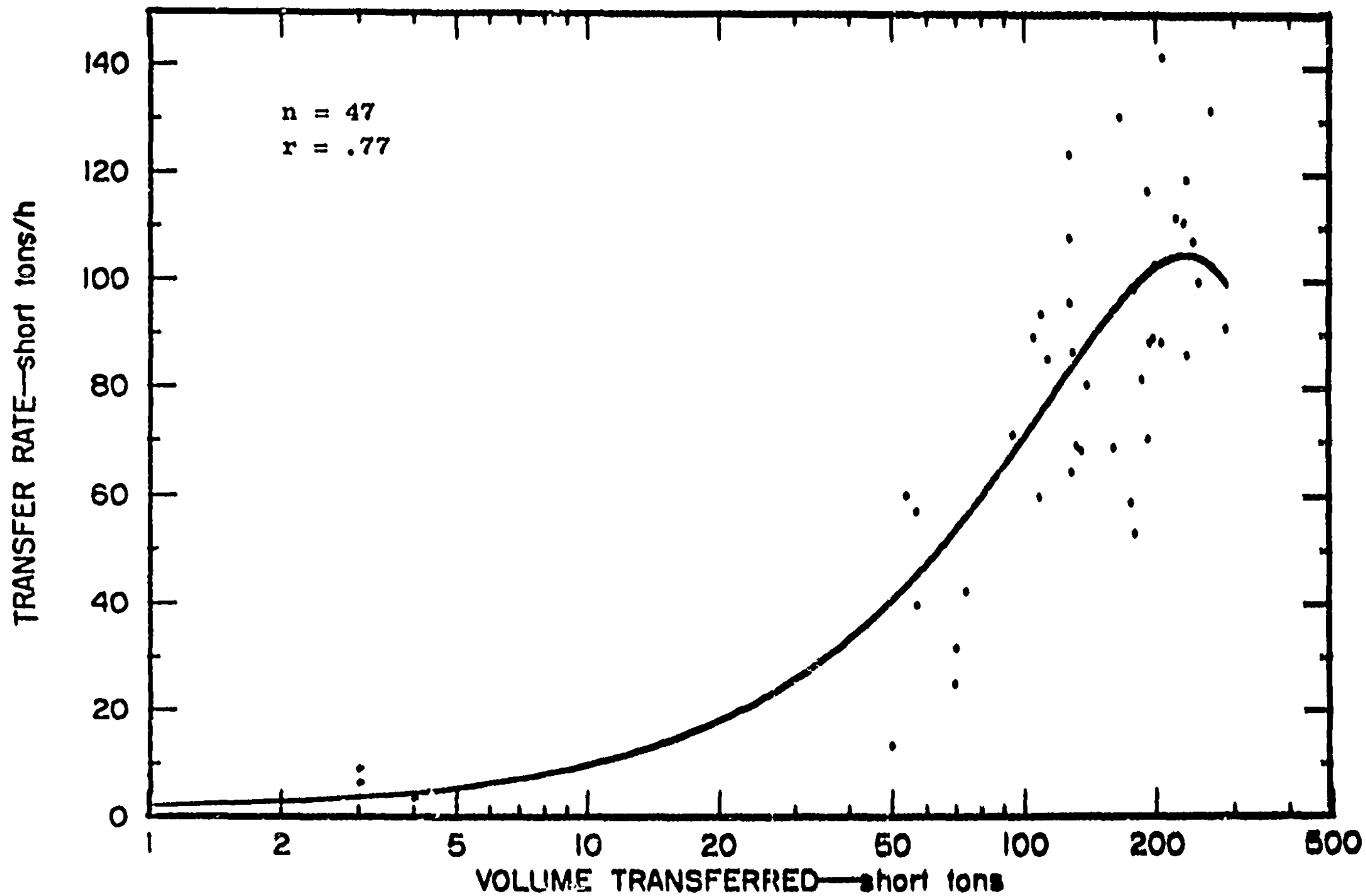

Figure 5 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVS TYPE BY AE AND AOE TYPES

d. Other Factors

Other factors that might have a bearing on replenishment effectiveness were examined through stepwise regression analysis and through additional analysis of the basic data. The regression analysis included regression of transfer time transfer rate on: quantity transferred, number of rigs used, rig-unrig time, total alongside time, transfer time, delay time, ship speed, whether simultaneous replenishments were in progress, whether replenishments were made during daytime or at night, and whether operations were in EastPac or WestPac. The EastPac-WestPac factor was also examined in greater detail through additional analysis of the basic data. The basic data were also used to reconstruct the operational histories of selected ships to determine whether effectiveness was affected by duration of deployment, by length of operational periods within the deployment, or by daily workload.

The first step in the regression analysis confirmed the finding of subsection c above that the quantity transferred has a predominating effect on transfer rate. This effect is so strong that no other factor except transfer time showed any significant effect at the 5% or higher level (recall that 1% is a higher significance level than 5%). To determine whether any other factors had secondary effects (i.e., effects that would be significant in analyzing replenishments

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(Continued from page 37.)

† In the application considered here, Y is the transfer rate and X is the quantity transferred. (Actually both X and X^2 are used as predictors, but the same principles apply.) For the transfer rate to be 50% predictable from the quantity transferred, i.e., that the dispersion of transfer rates around their predicted values (using transfer quantities) be one-half that of the rates alone, $\sqrt{1-r^2}$ must be 0.50, hence the correlation coefficient r must be 0.87. Since prediction of transfer rates is our principal objective, we will not interpret r as being large unless it is at least 0.9.

in which quantities transferred are equal), the quantity transferred and transfer time were eliminated from the regression model. When this was done, the following results ensued:

(1) Rig-unrig time had a negative effect on transfer rate (i.e., longer rig-unrig time was associated with reduced transfer rate), which was significant at the 1% level.

(2) WestPac transfer rates were higher than EastPac rates at the 1% significance level.

(3) Daytime transfer rates were higher than nighttime transfer rates at the 5% significance level.

(4) The number of lifts had a significant positive effect on transfer rate at the 1% level. Since the correlation between number of lifts and quantity transferred was 0.934, this result was not unexpected when quantity transferred was eliminated from the model.

Since the EastPac-WestPac factor was secondarily significant, it was examined further by reference to the basic data. Because of the strong relationship between transfer rate and quantity transferred, the data were examined to determine whether the EastPac-WestPac difference could be attributable to a difference in average quantity transferred in the two areas. It was found, however, that the average quantity of ordnance transferred was almost identical in EastPac and WestPac, as shown in the following tabulation:

	EastPac	WestPac
Average quantity of ordnance transferred (tons)	329.5	329.3
Standard deviation (tons)	150.0	170.9
Number of observations	37	449

It appears, therefore, that the transfer rate difference between EastPac and WestPac was in fact real and not a function of differences in other variables.

Effects of deployment duration, length of operational periods within the deployment, and daily workload were explored through detailed analysis of the operational histories of three representative AE deployments to WestPac. The deployments were divided into operational periods, defined as intervals in which replenishments were made on most days. A break of more than two days between replenishments would end a period. Thus, a period represented an interval of relatively sustained workload. Transfer rates in periods were analyzed sequentially to determine whether transfer rates changed as the length of the deployment increased; no significant temporal change could be found. Transfer rates within periods were also analyzed against period length to determine whether sustained operations affected transfer rates; no significant effect could be found. Transfer rates within periods were further analyzed against workload, which was measured both in terms of the average number of tons transferred per day and the average number of receiving ships serviced per day. No significant effect on transfer rate of either measure of workload could be found. Therefore, it was concluded that within the range of the observed data replenishment effectiveness was not affected by deployment duration, length of operational periods within the deployments, or average daily workload within the operational periods.

2. Provisions

a. Delivery Ship Type and Class

Average transfer time transfer rates for provisions transferred to CVs from different delivery ship types are given in the tabulation below, with the standard deviation of transfer rate and the number of observations.

Delivery Ship Type	Average Transfer Time Transfer Rate (tons/hr)	Standard Deviation of Transfer Time Transfer Rate (tons/hr)	Number of Observations
AF	91.45	36.07	90
AFS	75.64	25.43	29
AOE	37.81	49.20	9

Transfer rate for the AF class was significantly better than for the AFS at the 5% level, and significantly better than for the AOE at the 1% level. The AFS transfer rate was also better than the AOE rate at the 1% significance level. Thus, delivery ship type did have a strong effect on replenishment effectiveness in the case of provisions.

Before computing the average transfer rate for the AF type in the table above, a comparison was made of the transfer rates of the AF56 class, which comprises AF56-AF59, and the rates of the other AF ships. No significant difference could be found between the two groups.

b. Receiving Ship Type

Based on the analysis made in connection with ordnance transfers, it was considered appropriate to break the receiving ships into two groups, CVA-CVAN and CVS. The CVS would be expected to receive provisions at a lower transfer rate than the CVA-CVAN.

c. Quantity Transferred

The results described in the two foregoing subsections suggest that the effect on transfer rate of quantity of provisions transferred be subdivided as shown:

Delivery Class	Receiving Class
AF	CVA-CVAN
AF	CVS
AFS	CVA-CVAN
AFS	CVS
AOE	CVA-CVAN
AOE	CVS

Plots of transfer rate versus quantity of provisions transferred are presented for each of the above subdivisions, except AOE to CVS, as Figures 6 through 10, respectively. Since only one provisions transfer from AOE to CVS was observed, this subdivision was not plotted. The correlation coefficients for the second-degree, least squares curves and the curve parameters are shown in the following tabulation.

		Curve Parameters			
Delivery Class	Receiving Class	Intercept	Coefficient of Quantity Transferred	Coefficent of Square of Quantity Transferred	Correlation Coefficient
AF	CVA-CVAN	21.8147	0.5997	-0.00[illegible]1	0.65
AF	CVS	11.7499	0.5924	-0.0008	0.81
AFS	CVA-CVAN	13.3726	0.3812	-0.0004	0.84
AFS	CVS	-6.1749	1.2652	-0.0065	0.83
AOE	CVA-CVAN	0.8558	0.4382	-0.0012	0.98

The coefficients of correlation indicate that in most cases the empirical curves do not provide a good fit to the data. This may be confirmed visually by observing Figures 6 through 10. Therefore, it was concluded that use of the least squares empirical curves

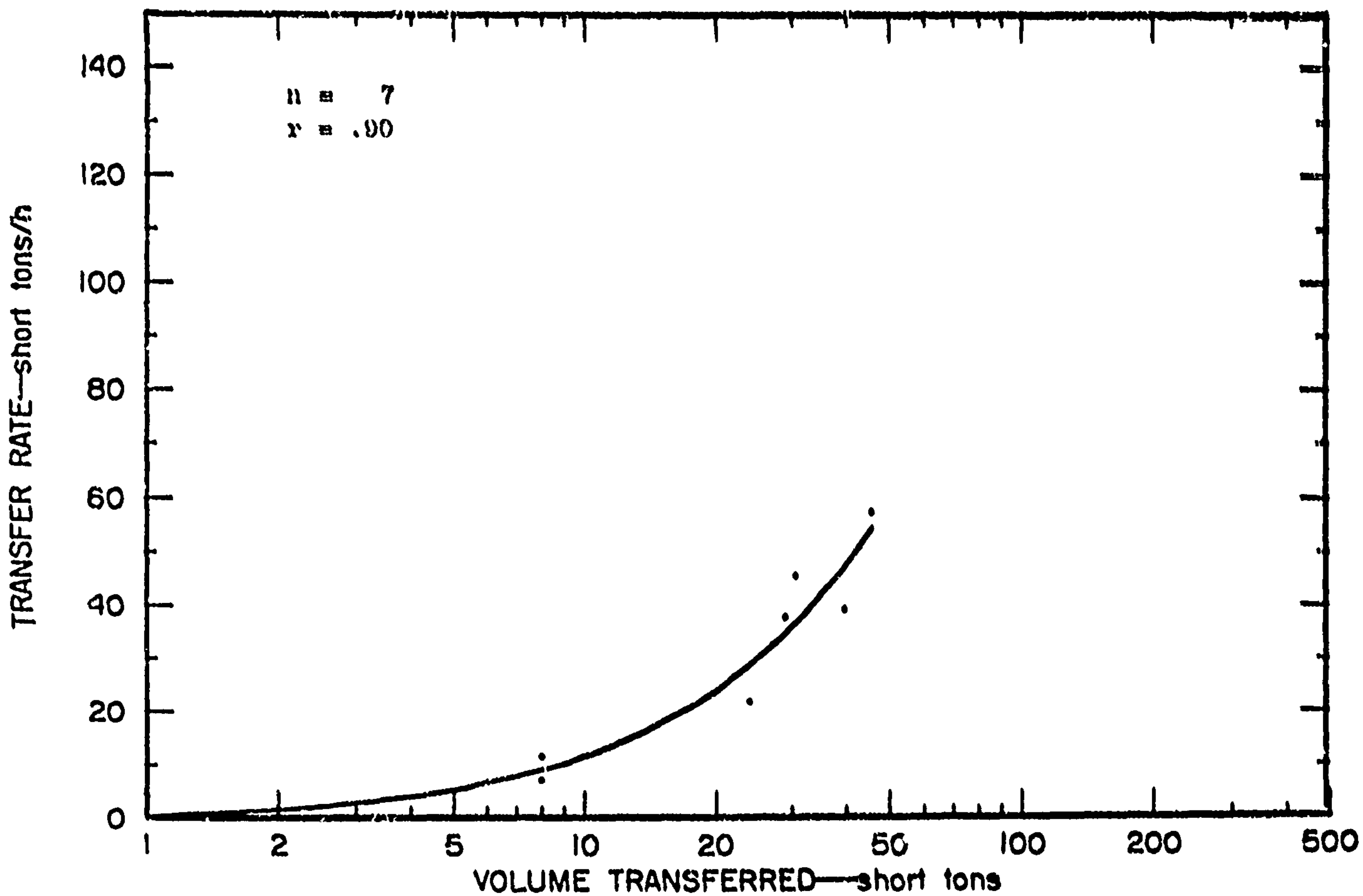

Figure 6 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CVA AND CVAN TYPES BY AF TYPE

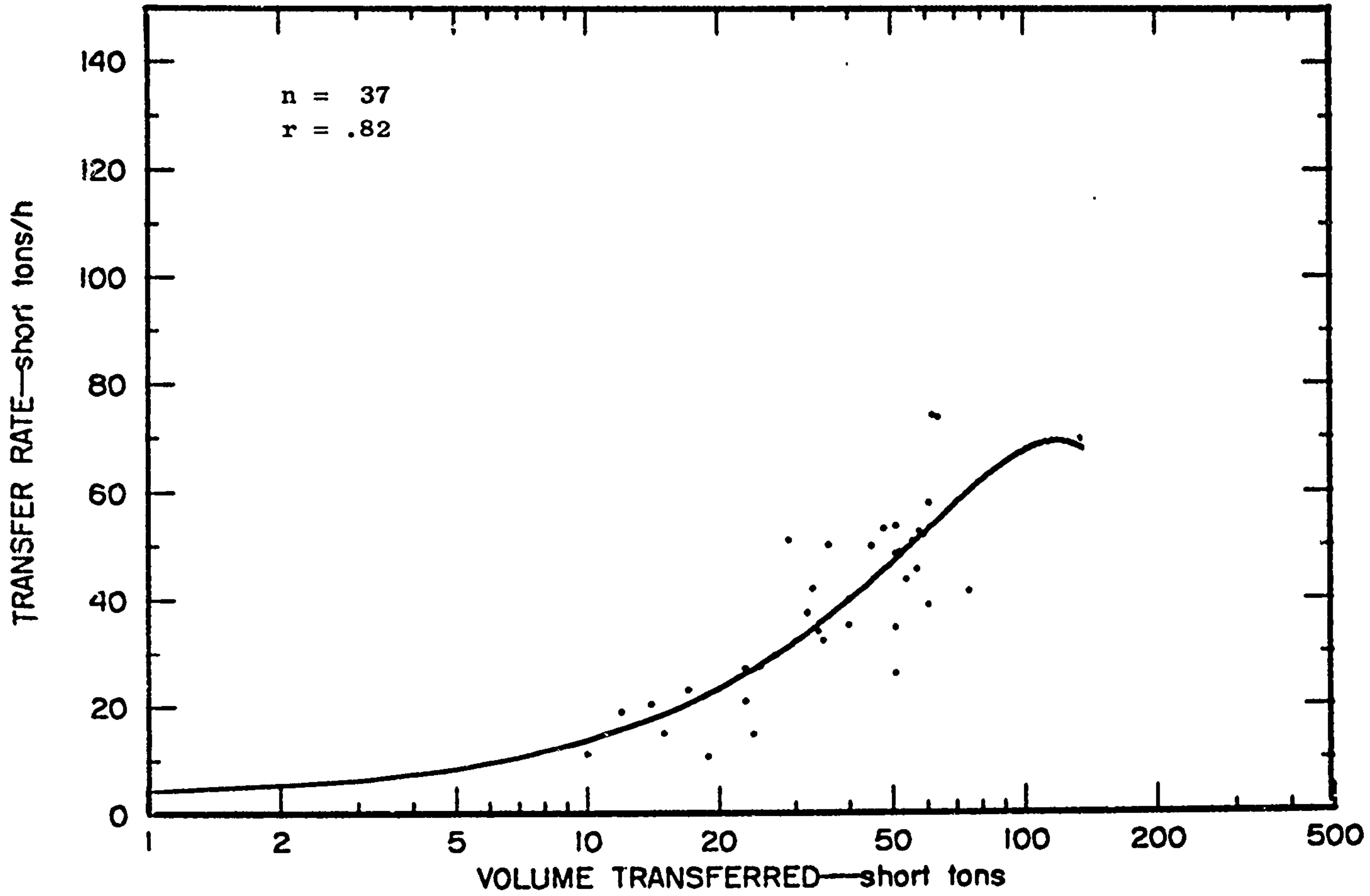

Figure 7 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CVS TYPE BY AF TYPE

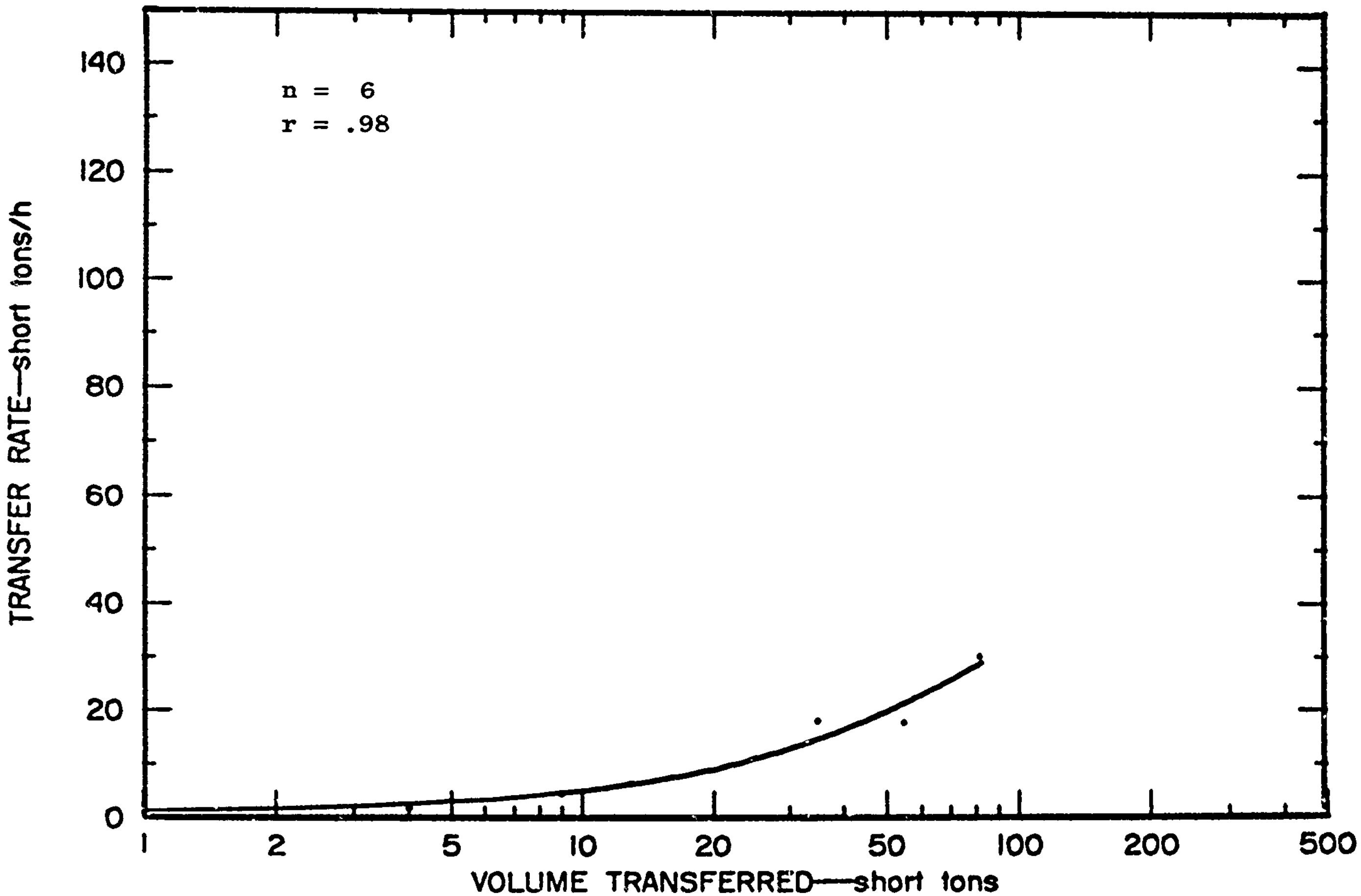

Figure 8 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CVA AND CVAN TYPES BY AFS BY TYPE

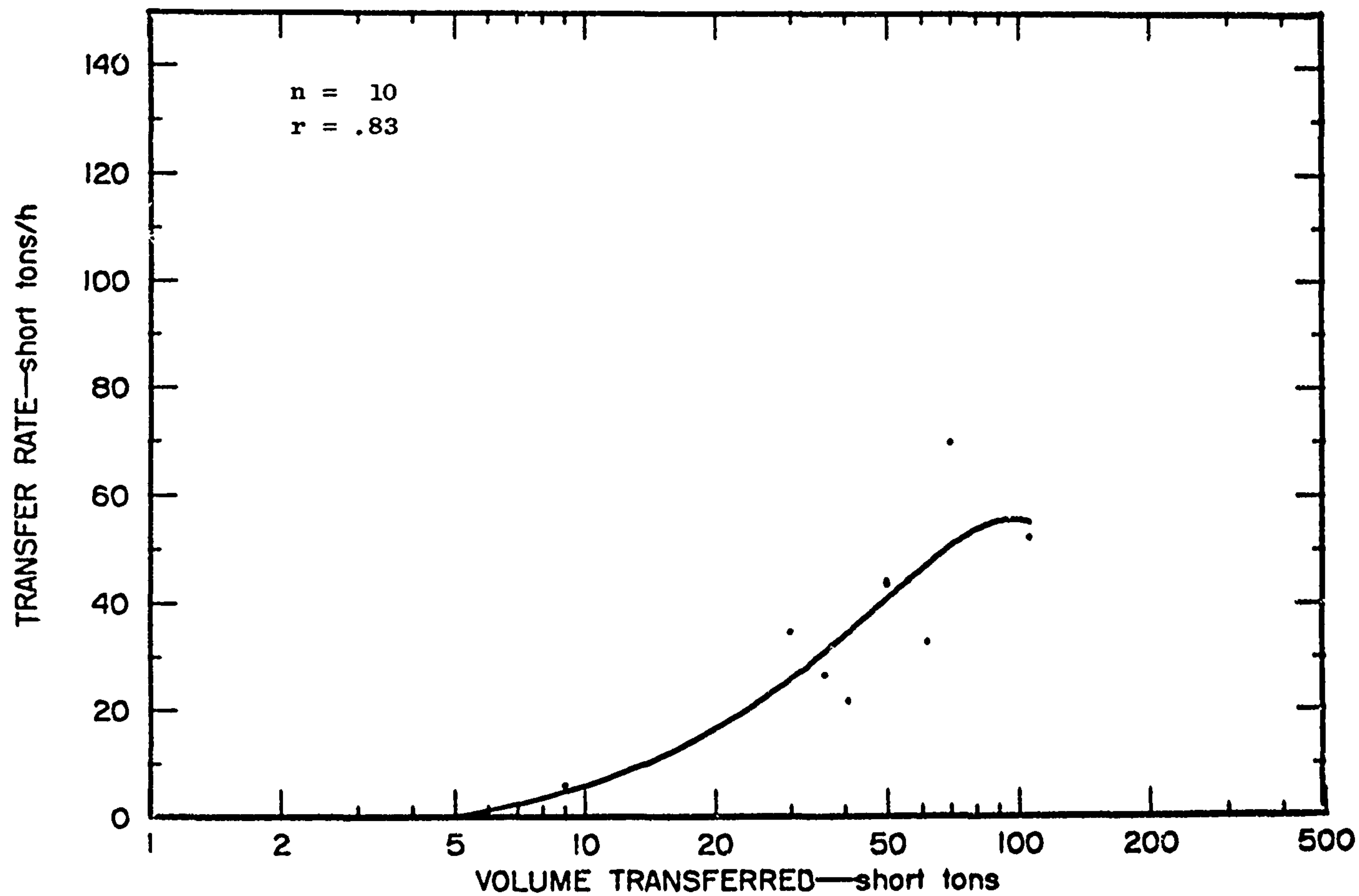

Figure 9 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CVS TYPE BY AFS TYPE

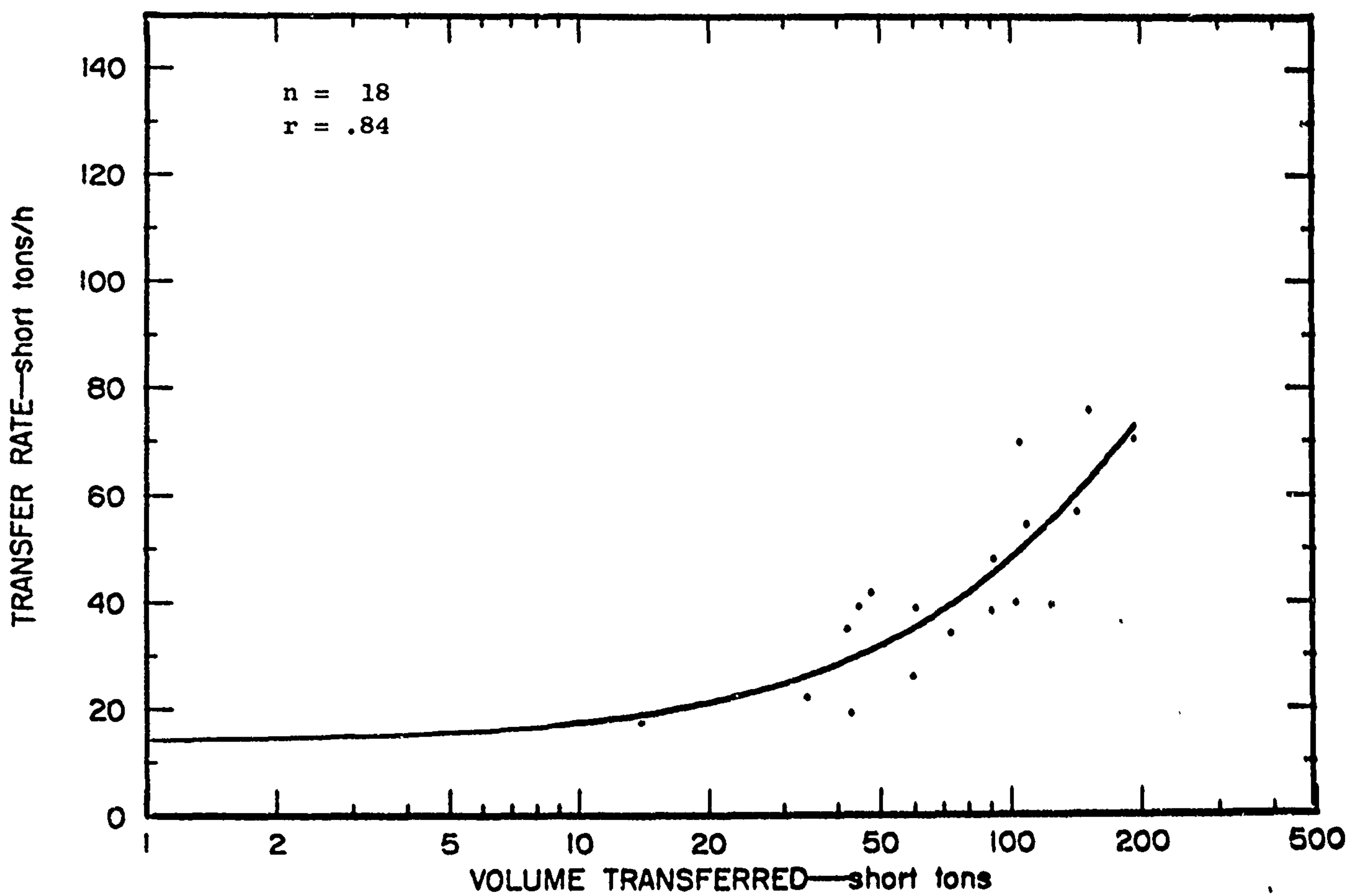

Figure 10 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CVA AND CVAN TYPES BY AOE TYPE

to predict transfer rate based on quantity transferred is not justified, even when these curves are particular to homogeneous performance groupings of delivery and receiving ship types.

3. Stores

a. Delivery Ship Type

Average transfer time transfer rates for stores transferred to CVs from different delivery ship types are given in the tabulation below, with the standard deviation of transfer rate and the number of observations.

Delivery Ship Type	Average Transfer Time Transfer Rate (tons/hr)	Standard Deviation of Transfer Time Transfer Rate (tons/hr)	Number of Observations
AFS	56.23	32.93	11
AKS	70.97	29.83	37
AOE	8.43	2.98	4

No significant difference in transfer rate could be found between the AFS and AKS types. The AOE sample was too small to permit any conclusions to be made about its performance, either in absolute terms or relative to AFS-AKS performance.

b. Receiving Ship Type

Based on the analysis made in connection with ordnance transfers, it was considered appropriate to divide the receiving ships into two groups--CVA-CVAN and CVS. The CVS would be expected to receive stores at a lower transfer rate than the CVA-CVAN.

c. Quantity Transferred

The results described in the two foregoing subsections suggest that the effect of quantity of stores transferred be subdivided and that the AOE be eliminated from further consideration. The subdivisions would be as follows:

(1) Stores transfers to CVA and CVAN from AFS and AKS.

(2) Stores transfers to CVS from AFS and AKS.

Plots of transfer rates versus quantity of stores transferred are presented for each of these subdivisions as Figures 11 and 12, respectively. The correlation coefficients for the second degree, least squares curves and their parameters are shown in the following tabulation.

	Curve Parameters			
Receiving Class	Intercept	Coefficient of Quantity Transferred	Coefficient of Square of Quantity Transferred	Correlation Coefficient
CVA-CVAN	3.0006	1.1085	-0.0046	0.81
CVS	-0.9787	1.2699	-0.0014	0.65

The coefficients of correlation indicate that the quantity transferred is not by itself an adequate predictor of transfer rate. This may be confirmed visually by observing Figures 11 and 12. It was therefore concluded that use of the least squares empirical curves to predict transfer rate based on quantity transferred is not justified, even when these curves are particular to homogeneous performance groupings of delivery and receiving ship types.

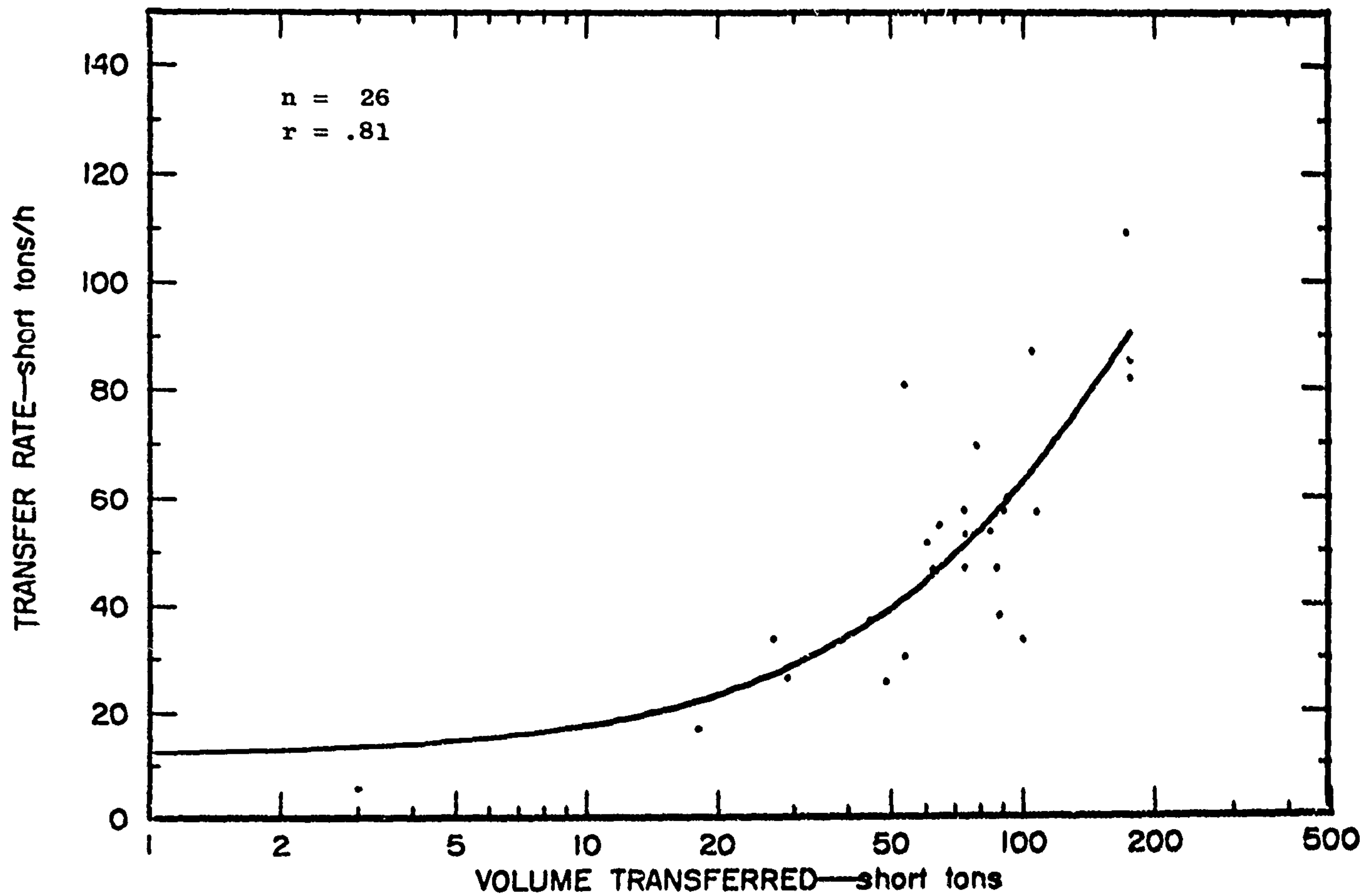

Figure 11 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF CVA AND CVAN TYPES BY AFS AND AKS TYPES

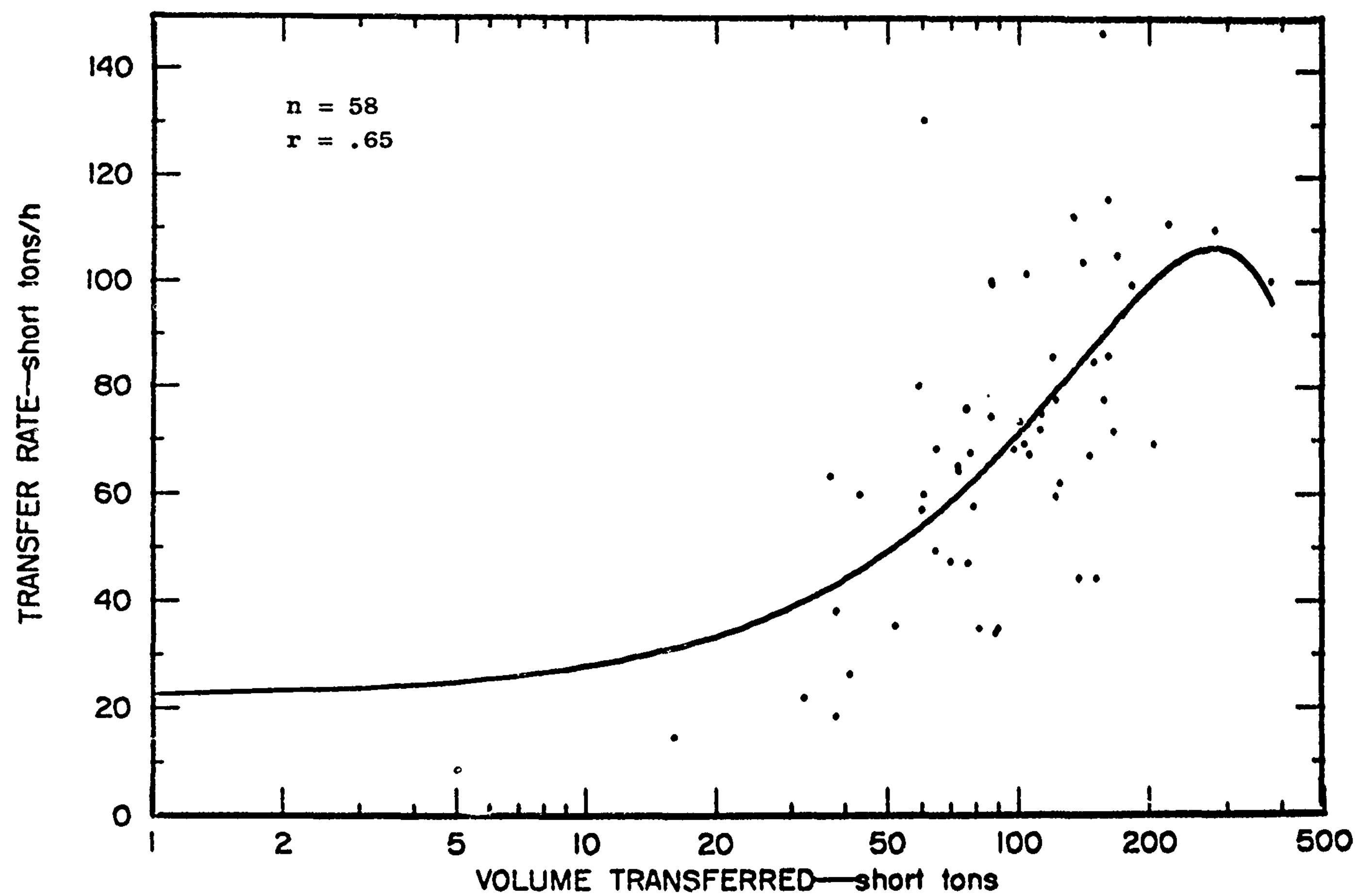

Figure 12 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF CVS TYPE BY AFS AND AKS TYPES

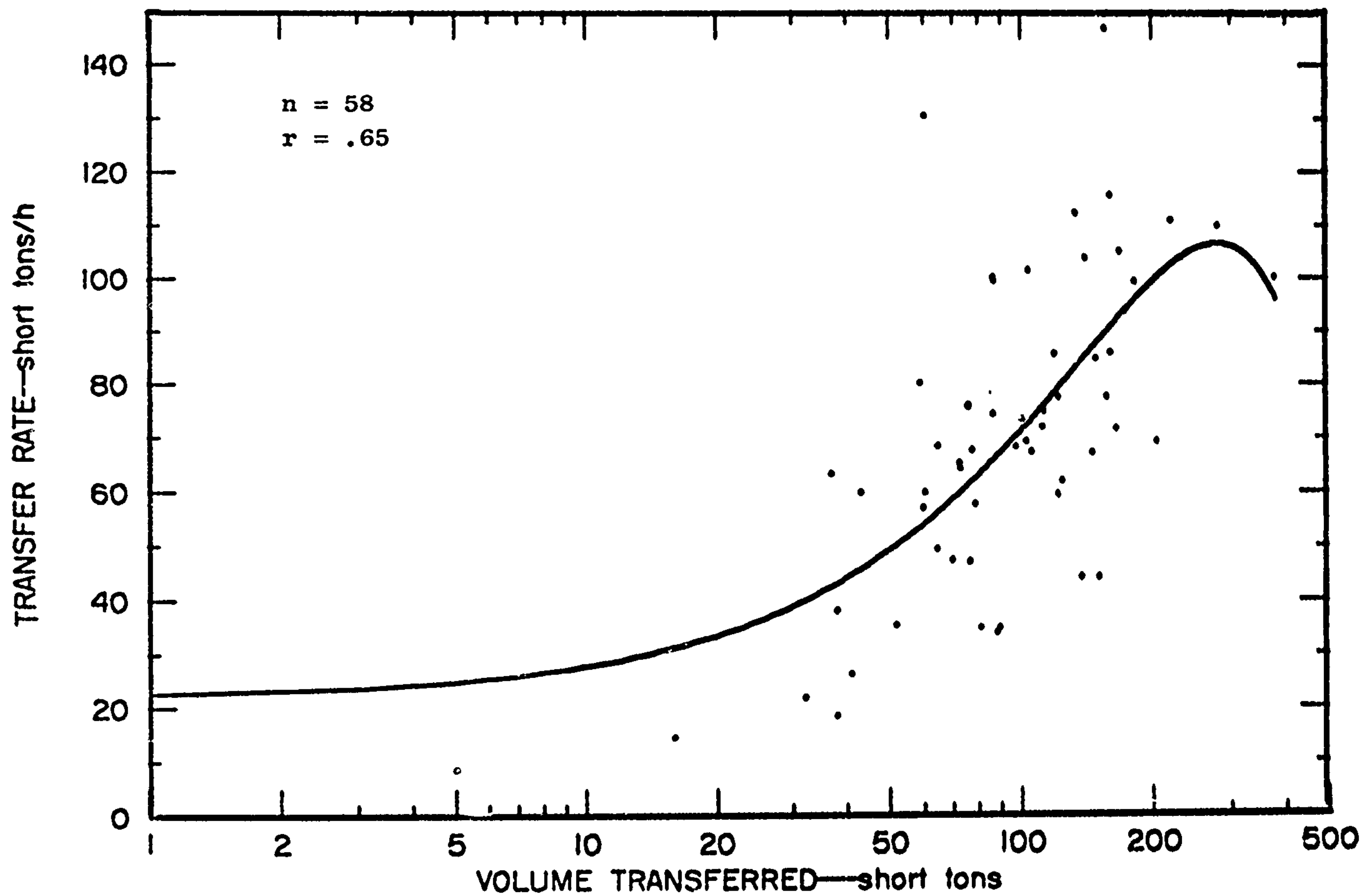

Figure 12 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF CVS TYPE BY AFS AND AKS TYPES

C. Connected Transfers of Fuel

Connected transfers of fuel to CVA, CVAN, and CVS ship types were analyzed in detail. This group of ships was selected for detailed analysis because, being relatively homogeneous, it would be expected to exhibit minimal intership variability. The types of fuel were NSFO ship fuel (not used by the CVAN) and JP fuel for turbine-powered aircraft. The following subsections present the results of detailed analysis of fuel transfers by type of receiving ship and by type and class of delivery ship, respectively.

1. Receiving Ship Class

The mean pumping rates at which the CVAN, CVA and CVS types received JP and at which the CVA and CVS received NSFO are shown below.

	Mean Pumping Rates (bbl/hr)	
	JP	NSFO
CVAN	6727	N/A
CVA	6247	6286
CVS	4688	4743

No significant difference was found between the JP and NSFO receiving rates for either the CVA or CVS type. The CVS categories received JP significantly more slowly (at the 1% level) than did the CVAs and the CVAN. There was no significant difference between the receiving rates of the CVAs and of the CVAN. The CVSs also received NSFO significantly more slowly (at the 1% level) than did the CVAs. As will be explained in the following paragraphs, part of these differences is attributable to differences in quantities transferred.

A regression analysis was conducted on transfers of JP to the CVA-CVAN group to determine whether pumping rate is significantly dependent on any one or more of the following variables:

- Quantity transferred
- Ship speed
- Rig-unrig time
- Number of hoses
- Delay time
- Whether replenishment occurred in daytime or at night
- Whether replenishment was in EastPac or WestPac.

The results of the regression analysis showed pumping rate to be dependent at the 1% significance level on quantity transferred and on number of hoses. None of the other variables was significant. (In another analysis that was made of JP transfers to the CVA-CVAN group from the AO 105 class only, delay time was also significant, but only at the 5% level.) This dependence on quantity transferred accounts for part of the difference in pumping rates between the CVA-CVAN group and the CVSs; in the case of JP, the average quantity received by the CVA-CVAN group was 10,502 barrels, whereas the average quantity received by the CVSs was 5357 barrels. This difference in quantities is significant at the 1% level.

2. Delivery Ship Type and Class

Detailed analysis of fuel transfers by delivery ship type and class was limited to transfers of JP and NSFO to CVAs. Presented below, in descending order of pumping rates, are the mean pumping rate, mean pumping rate per hose, mean number of hoses used per replenishment, and number of cases examined.

Delivery Ship Type and Class	Mean Pumping Rate (bbl/hr)	Mean Pumping Rate per Hose (bbl/hr)	Mean Number of Hoses	Number of Cases
AO 105	7352	3354	2.25	131
AO 143	6552	2915	2.38	181
AOE	5817	2865	2.14	147
AO 22	5110	2580	2.08	95

All differences in mean pumping rate were significant at the 1% level; however, this was not the case with mean pumping rate per hose. The mean pumping rate per hose of the AO 105 class was significantly higher at the 1% level than all the other rates, and the rate for the AO 143 class was significantly higher at the 1% level than the rate for the AO 22 class. However, no statistically significant difference could be found between the mean pumping rates per hose of the AO 143 class and AOE type or between those of the AOE type and the AO 22 class. Thus, differences in overall pumping rates among AO classes appear to be attributable chiefly to differences in pumping rates per hose, whereas differences in overall pumping rates between the AO 143 class and the AOE type, and between the AOE type and the AO 22 class, are probably attributable largely to differences in the number of hoses used and in average quantities of fuel transferred per replenishment.

D. Vertical Replenishments

The analysis of vertical replenishments was directed toward determining:

(1) Whether and under what conditions the use of two helicopters from a single delivery ship improved replenishment rate over the rate resulting from use of a single helicopter.

(2) The effect of replenishment range on vertical replenishment rate.

1. Vertical Replenishment Rate Improvement Using Two Helicopters

The data for vertical replenishments to non-CV ships from AFS and AOE classes were analyzed to investigate whether replenishment rates were improved when two helicopters instead of one where used to a single receiving ship. A total of 690 vertical replenishment cases, broken down as shown in Table 2, were examined.

Table 2

BREAKDOWN OF 690 VERTICAL REPLENISHMENT CASES

Range Interval (yds)	Number of Cases Included in Analysis*		
	Single Helicopter	Two Helicopters	All Cases
All distances	498	192	690
All distances more than 100 yds	410	188	598
50	78	2	80
100	10	2	12
101-1000	260	110	370
1001-2000	68	23	91
2001-3000	15	12	27
3001-4000	23	9	32
4001-5000	3	4	7
5001-6000	14	5	19
6001-7000	2	0	2
More than 7000	25	25	50

*Editing for consistency and credibility resulted in some reported transfers being removed from consideration in the analysis.

Table 3 presents the average replenishment rates for all vertical replenishments (i.e., both single-helicopter and two-helicopter replenishments). Average rates for single-helicopter and two-helicopter replenishments are also presented, along with the significance level and the percentage improvement resulting from using a second helicopter. The overall improvement in observed average rates varied from range to range; however, in no case did the addition of the second helicopter significantly decrease the average replenishment rate.

Whenever the average replenishment rates for single-helicopter and two-helicopter deliveries are not significantly different, the combined average transfer rate for all replenishments is the appropriate estimate of the individual rates for single-helicopter and two-helicopter replenishments. Admitting judgment to the analysis permits some additional inferences, such as the following, to be drawn.

- At a replenishment range of 50 yards, only two two-helicopter replenishments occurred out of the 80 replenishments observed. (The data editing process removed three single-helicopter replenishments, thus only 77 of the 80 observed replenishments were included in the analysis.) Primarily because of the small number of occurrences of two-helicopter replenishments, the average transfer rates were not determined to be significantly different. However, the observed average two-helicopter rate was 2.8 tons/hr below the single-helicopter rate. The fact that there were so few two-helicopter replenishments at this short range implies that previous experience had uncovered problems or inefficiencies in using two helicopters. If this

Table 8

EFFECTS OF NUMBER OF HELICOPTERS AND RANGE ON VERTICAL REPLENISHMENT RATE

Replenishment Distance (yards)	All Replenishments	1-Helicopter Replenishments	2-Helicopter Replenishments	Statistical Significance Level of Difference Between 1- and 2-Helicopter Replenishments (percent)	Replenishment Rate Improvement Using Two Helicopters instead of One (percent)
All distances	14.40	13.02	16.40	1%	21%
All distances more than 100 yards	13.94	12.83	16.38	1%	28%
50	17.11	17.18	14.37	None determined	n.a.
100	20.03	18.85	25.01	None determined	n.a.
101-1000	15.70	14.66	18.20	1%	24%
1001-2000	12.50	10.79	17.56	1%	63%
2001-3000	12.81	10.57	15.58	None determined	n.a.
3001-4000	10.95	10.51	12.00	None determined	n.a.
4001-5000	12.55	9.14	15.10	5%	65%
5001-6000	8.83	6.92	14.19	5%	105%
6001-7000	10.56	10.56	No two-helicopter replenishments		
More than 7000	8.28	6.82	9.82	None determined	n.a.

inference is correct, it could be further inferred that use of two helicopters at 50 yards would result in lower replenishment rates.

- At a replenishment range of 100 yards, two-helicopter replenishments occurred out of the total of 12 replenishments. Again primarily because of the small number of two-helicopter replenishments, no significant difference was determined between the average transfer rates. At this range, however, the observed two-helicopter replenishment rate was higher than the observed single-helicopter rate. The increased frequency of two-helicopter replenishments at 100 yards versus 50 yards (17% vs. 2.5%) suggests that two-helicopter replenishments may begin to become practical at about 100 yards.

- Observations in the range intervals 2001 to 3000 yards, 3001 to 4000 yards, and more than 7000 yards were so variable that no significant differences were found. It should be noted, however, that the 2001 to 3000 yard case was very nearly significant at the 5% level, and that in both the other cases the observed average two-helicopter rates were somewhat higher than the observed average single-helicopter rates. In view of the consistent pattern of higher two-helicopter rates in other range intervals more than 100 yards, it is probable that true rate differences exist in these intervals also.

Additional analysis was performed to determine whether the type of delivery ship (i.e., whether AFS or AOE) had any effect on the improvement of replenishment rate resulting from the use of two helicopters rather than one. Only replenishment ranges greater than 100 yards were included in this analysis. In the case of the AFS, it was found that use of two helicopters increased replenishment rate to 16.48 tons/hr from the 12.73 tons/hr single-helicopter replenishment rate. This 29% increment, significant at the 1% level, compares with the 28% increment presented in Table 3 for replenishments from both AFS and AOE at ranges of more than 100 yards. No significant increment could be found in the case of the AOE, probably because there were only three two-helicopter replenishments in the 47 total replenishments from AOE at more than 100 yards. Therefore, it was concluded that delivery ship type had no discernible effect on the improvement in replenishment rate resulting from the use of two helicopters.

2. <u>Effect of Range on Vertical Replenishment Rate</u>

An investigation was conducted to determine the effect of replenishment range on vertical replenishment rate. It was previously shown in Table 3 that the rate appears to decrease in more distant range intervals; however, a more thorough analysis appeared to be necessary.

To analyze the effects of range on replenishment rate, three regressions of range on replenishment rate were made. The first regression was made using the complete set of 830 cases that included single-helicopter and two-helicopter replenishments to all ship types including CVs. The second regression included only the 604 single-helicopter cases extracted from this set, and the third included only the 226 two-helicopter cases extracted from the set.

The regressions were performed by computer, which computed and plotted the second-degree, least squares regression lines. These lines and the raw data points for all cases, for the single-helicopter cases and for the two-helicopter cases, are presented in Figures 13, 14, and 15, respectively. The correlation coefficients for these curves are as follows:

	Correlation Coefficients
All cases	0.251
Single-helicopter cases	0.251
Two-helicopter cases	0.312

The curves in Figures 13, 14, and 15 appear to indicate that vertical replenishment rate decreased with range. However, the small correlations indicate that the curves, although they are the best possible second-degree fits to the data, do not fit the data closely. Therefore, to determine whether replenishment rate was indeed affected by range, an analysis of variance of data in different range intervals was made. The analysis included data for both single-helicopter and two-helicopter replenishments. The intervals were as follows:

Range Interval (yds)
101 - 1000
1001 - 2000
2001 - 3000
3001 - 4000
4001 - 5000
5001 - 6000
6001 - 7000
more than 7000

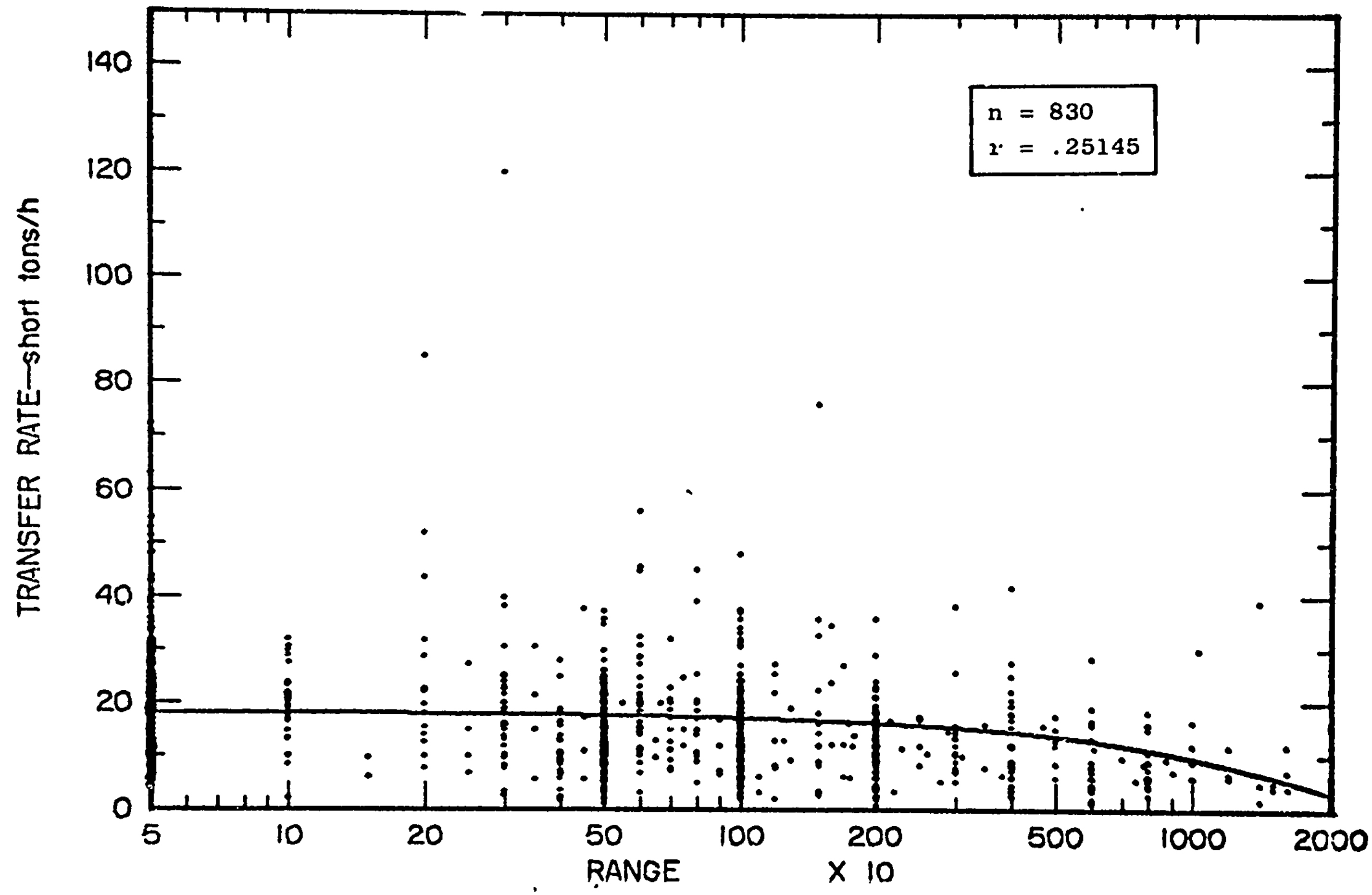

Figure 13 TRANSFER RATE VERSUS RANGE FOR ALL VERTICAL REPLENISHMENTS

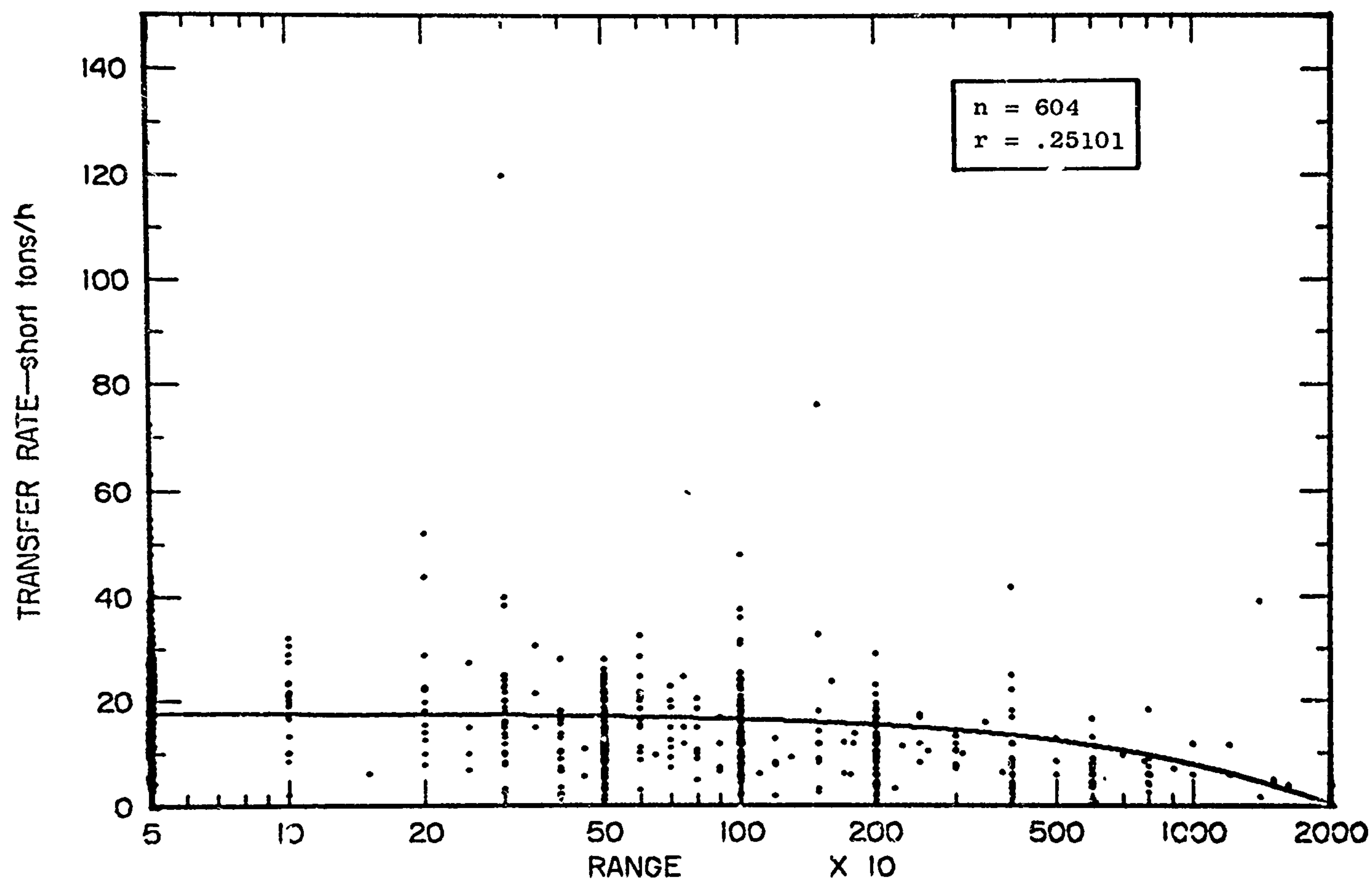

Figure 14 TRANSFER RATE VERSUS RANGE FOR VERTICAL REPLENISHMENTS IN WHICH ONE HELICOPTER WAS USED

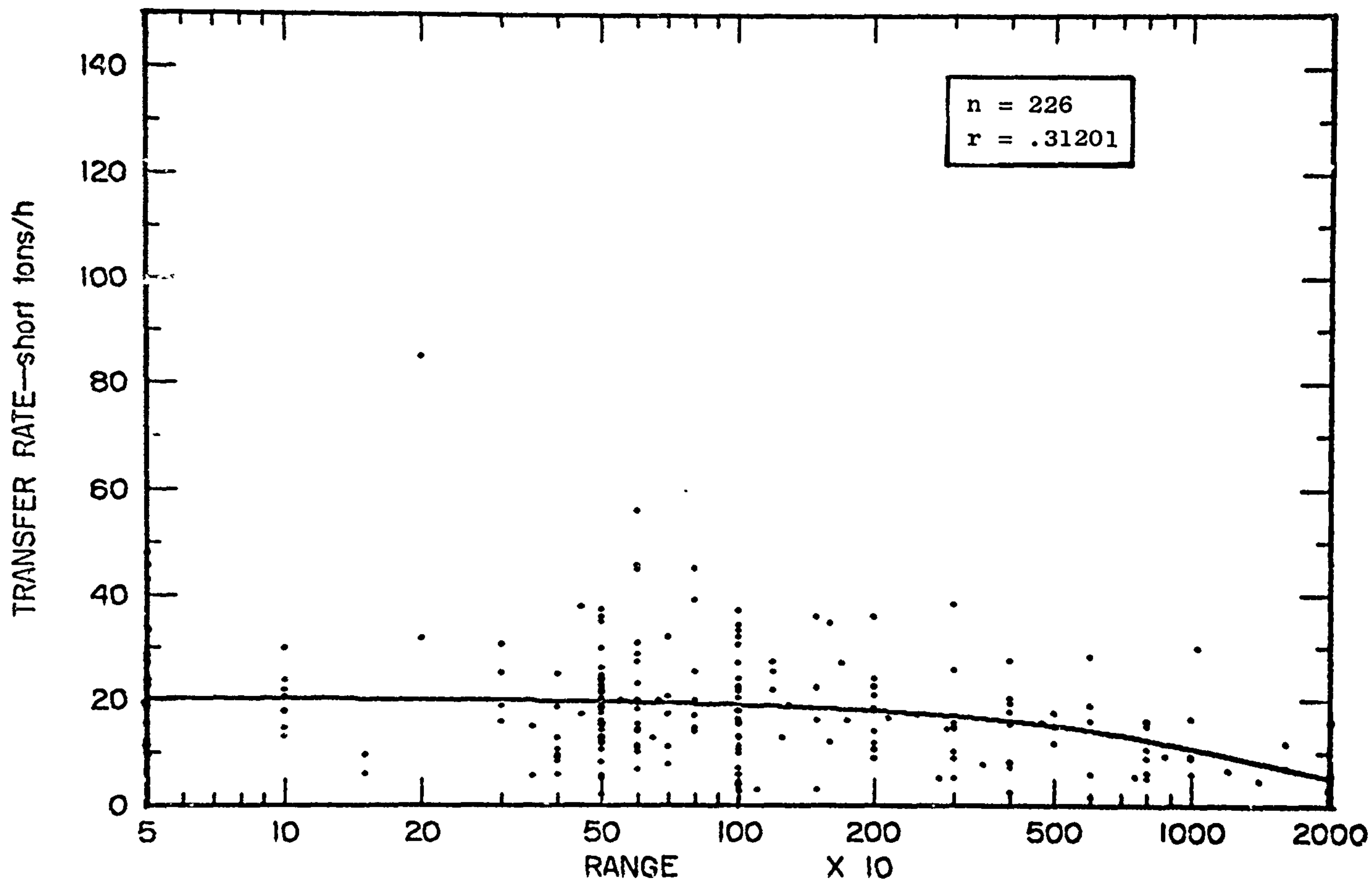

Figure 15 TRANSFER RATE VERSUS RANGE FOR VERTICAL REPLENISHMENTS IN WHICH TWO HELICOPTERS WERE USED

Considering the above intervals as a grouping, no statistically significant differences among replenishment rates could be found. However, the 101 to 1000 yard interval replenishment rate was significantly higher at the 1% level than the other intervals combined and than each of the other intervals taken individually. In addition, the 1001 to 2000 yard interval replenishment rate and the 2001 to 3000 yard rate were significantly higher (at the 1% and 5% levels, respectively) than the rate for the more than 7000 yard interval. No other significant differences were found between any other pairs of intervals. Therefore, replenishment rates did not change significantly with increasing range in replenishments at more than 1000 yards except in broad increments of distance.

The lack of an identifiable continuous relationship between replenishment rate and range may be partly attributable to the relationship between replenishment rate and quantity transferred. This relationship, which has already been shown in the case of connected replenishments, also exists among vertical replenishments. In fact, in the pairwise correlations of variables made as a part of the analysis described earlier, the correlation between replenishment rate and quantity transferred was 0.54. This was higher than any other pairwise correlation except those between variables that are inherently highly correlated (e.g., quantity transferred and number of lifts). By contrast, the correlation between replenishment rate and range was only -0.25, or less than one-half the absolute value of the rate-quantity correlation. The relationship between vertical replenishment rate and quantity transferred is shown in Figure 16; the second-degree, least squares curve fitted to these data has a correlation coefficient of 0.55, which is considerably higher than the value of 0.251 computed for the rate-range data.

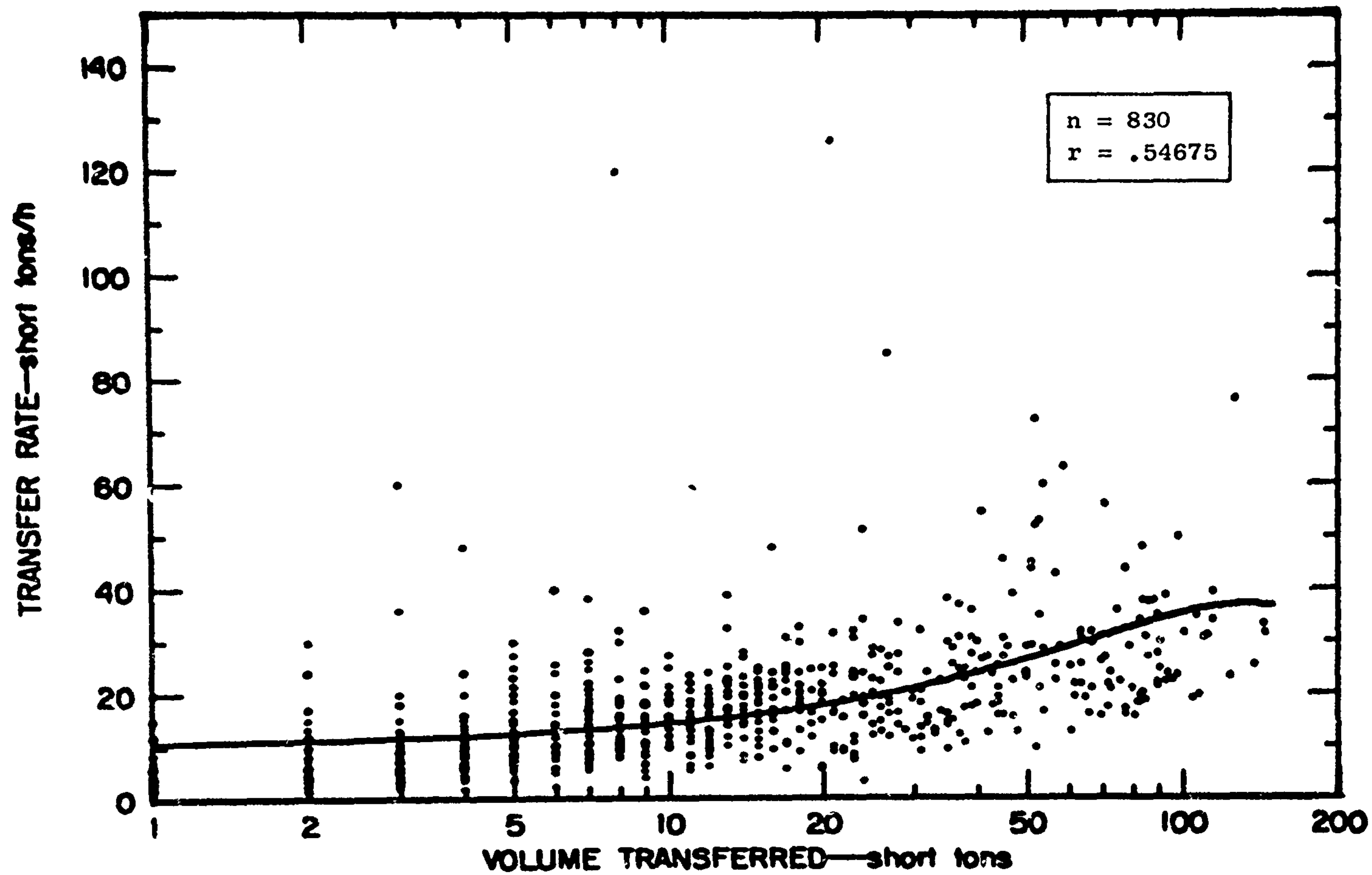

Figure 16 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ALL VERTICAL REPLENISHMENTS

APPENDIX

This Appendix presents quadratic regression plots of transfer rate versus quantity transferred that were used in the analysis but do not appear in the main report. The plots are organized generally by commodity type, and within commodity type of transfer conditions and location, by receiving ship type and by delivery ship type. Most of the plots have logarithmic scales on the abscissa; however, some have linear scales.

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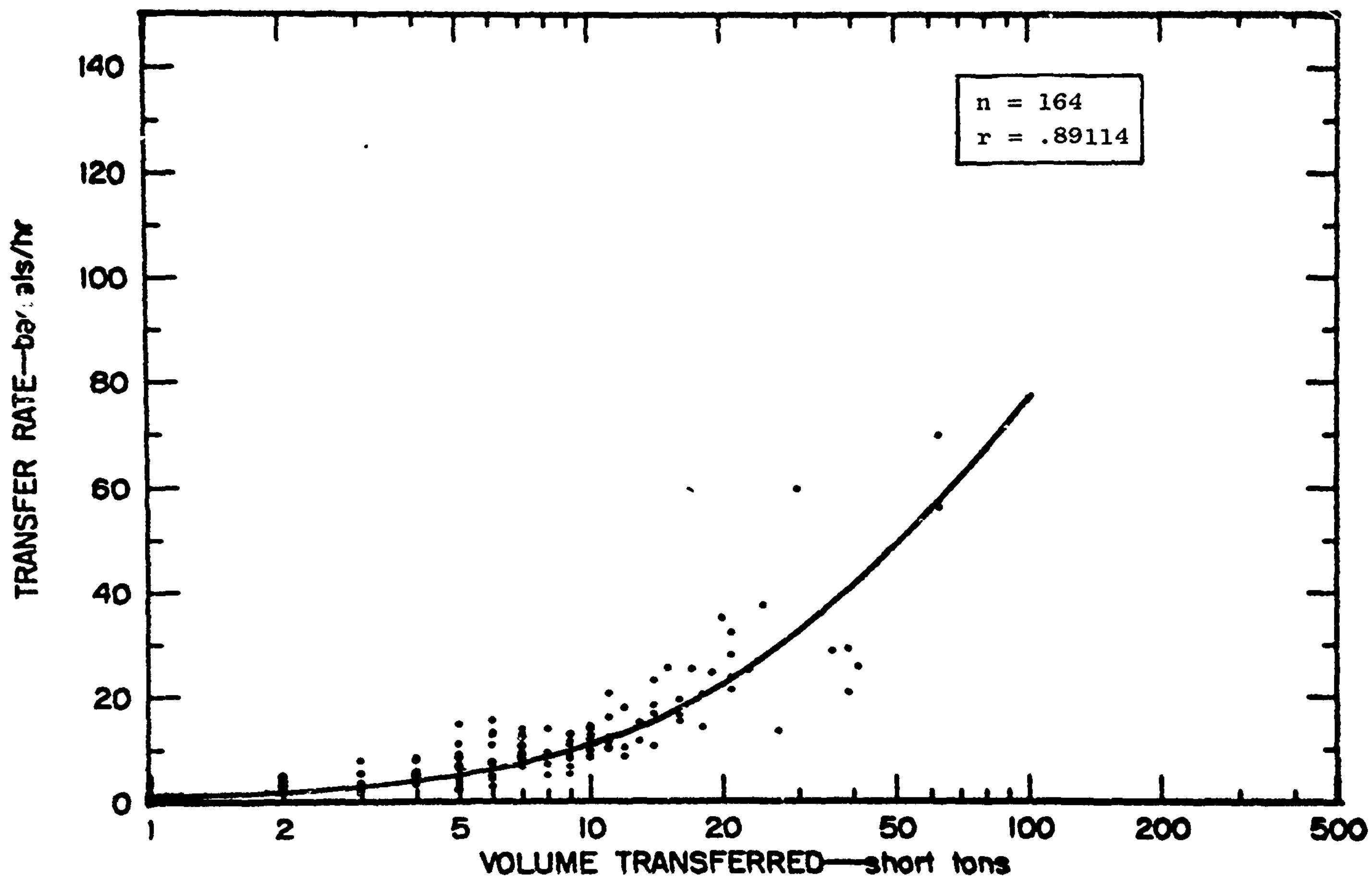


Figure A-1 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE, PROVISIONS AND STORES REPLENISHMENTS OF DL, DLG AND DLGN TYPES

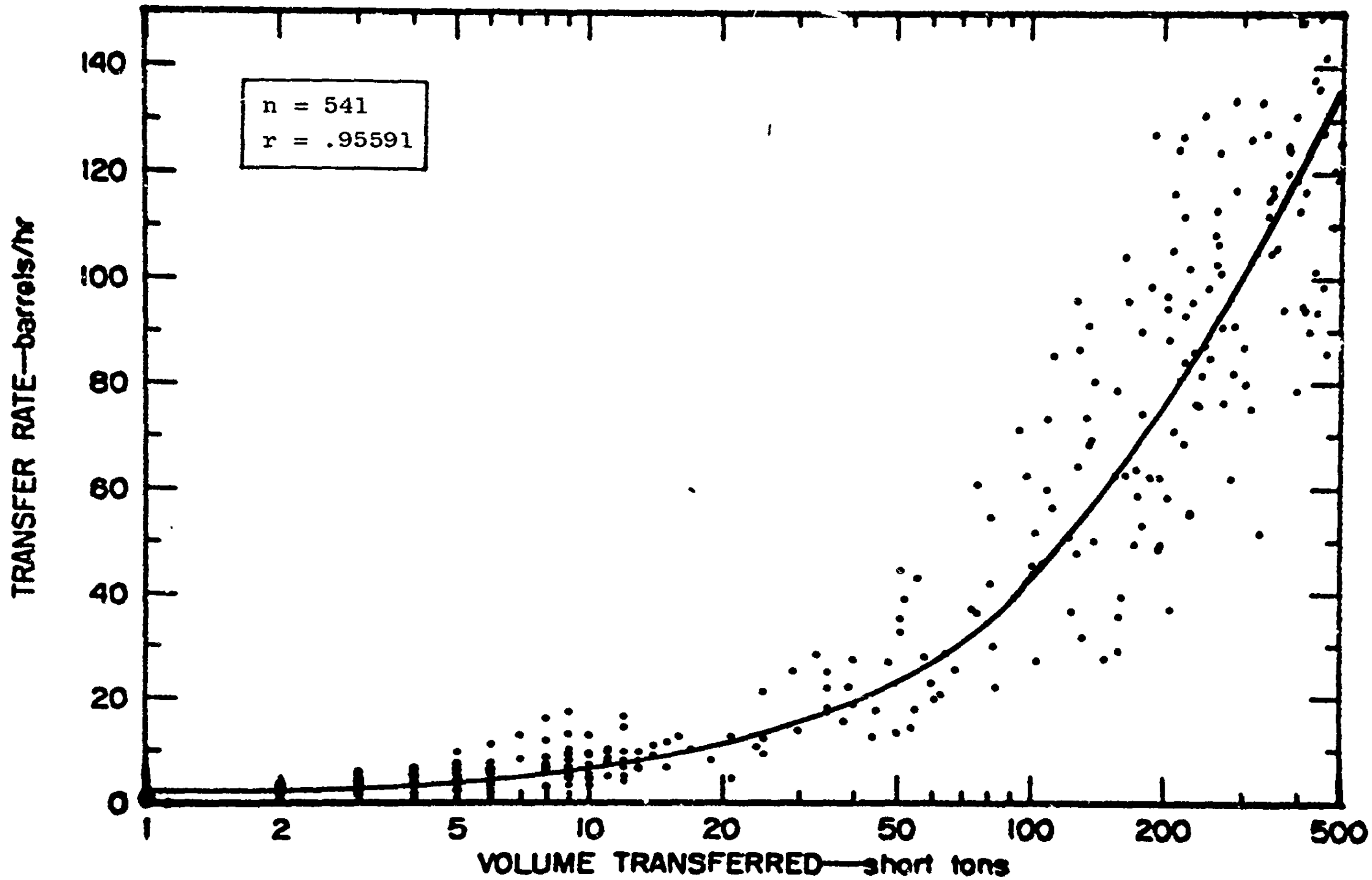


Figure A-2 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE, PROVISIONS AND STORES REPLENISHMENTS BY AOE TYPE

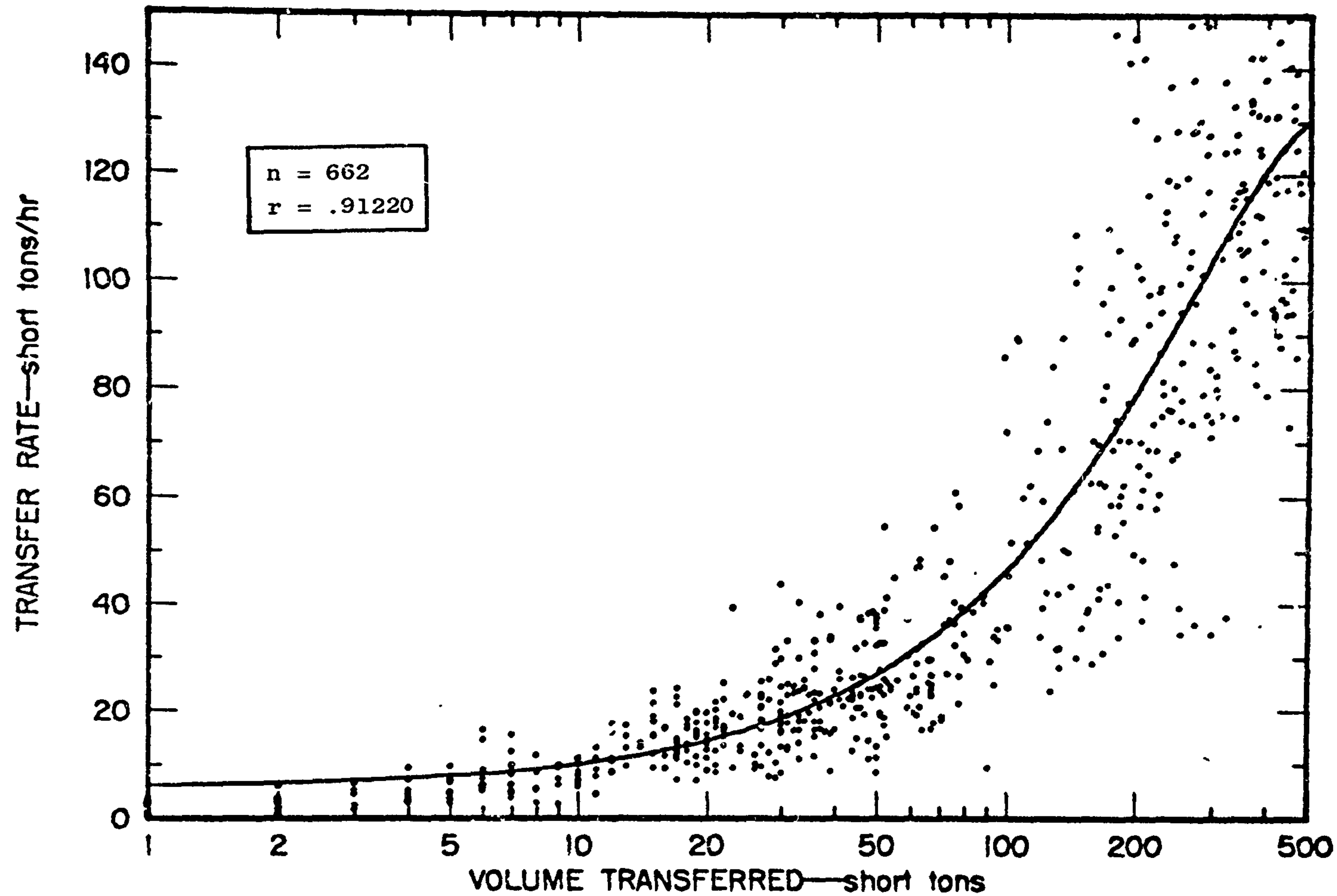


Figure A-3 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NIGHTTIME ORDNANCE REPLENISHMENTS

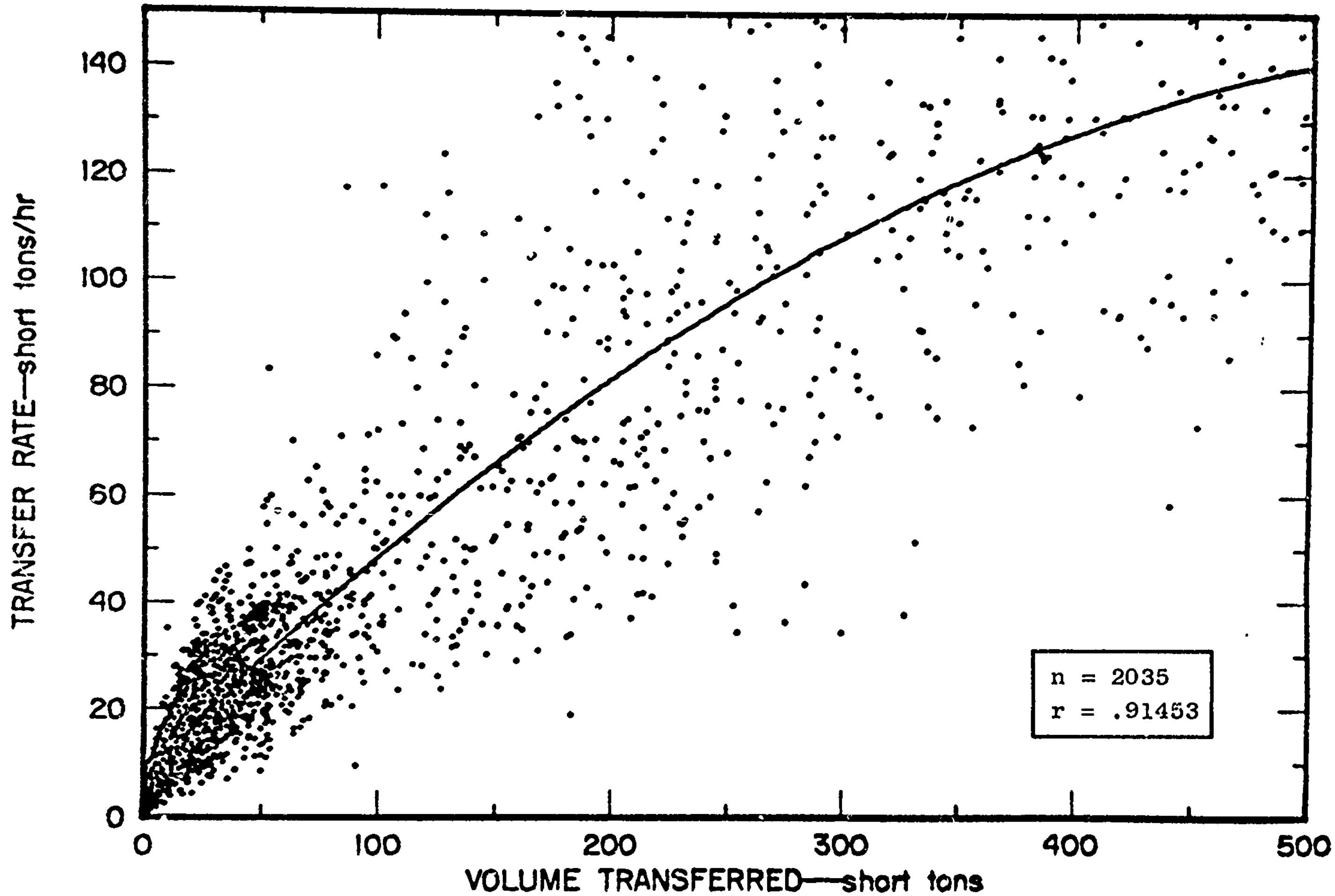


Figure A-4 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS IN WESTPAC

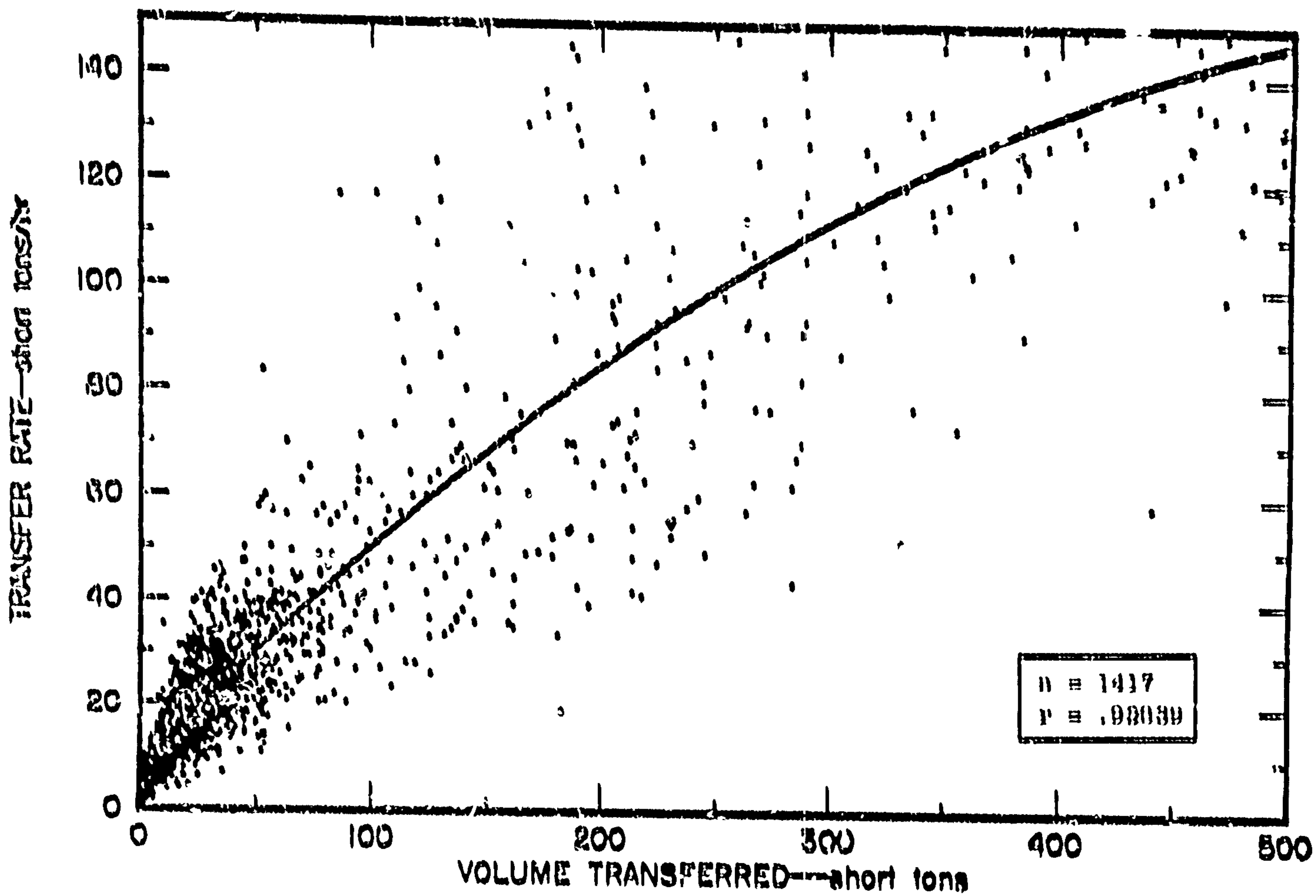


Figure A-8 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR DAYTIME ORDNANCE REPLENISHMENTS IN WESTPAC

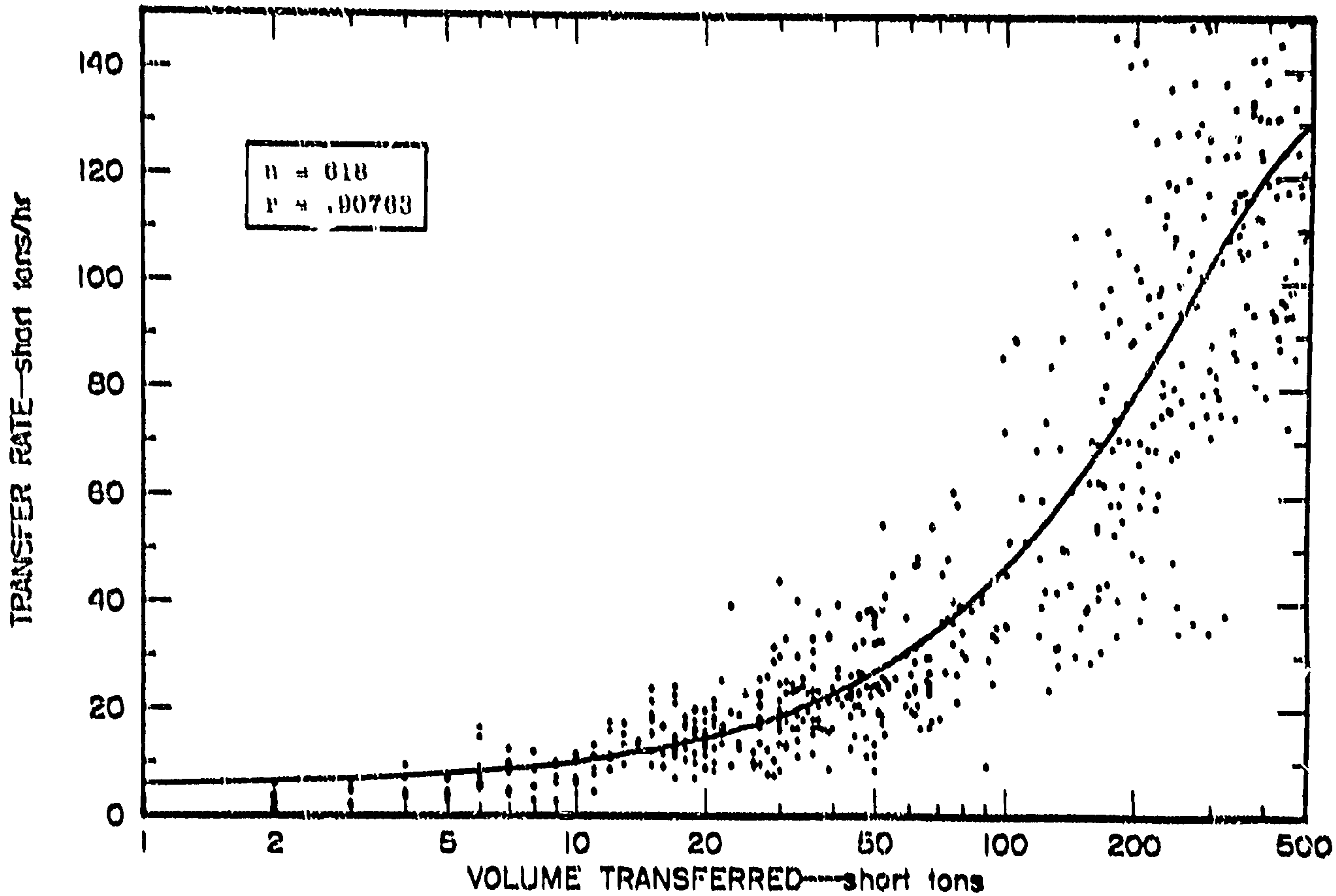


Figure A-6 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NIGHTTIME ORDNANCE REPLENISHMENTS IN WESTPAC

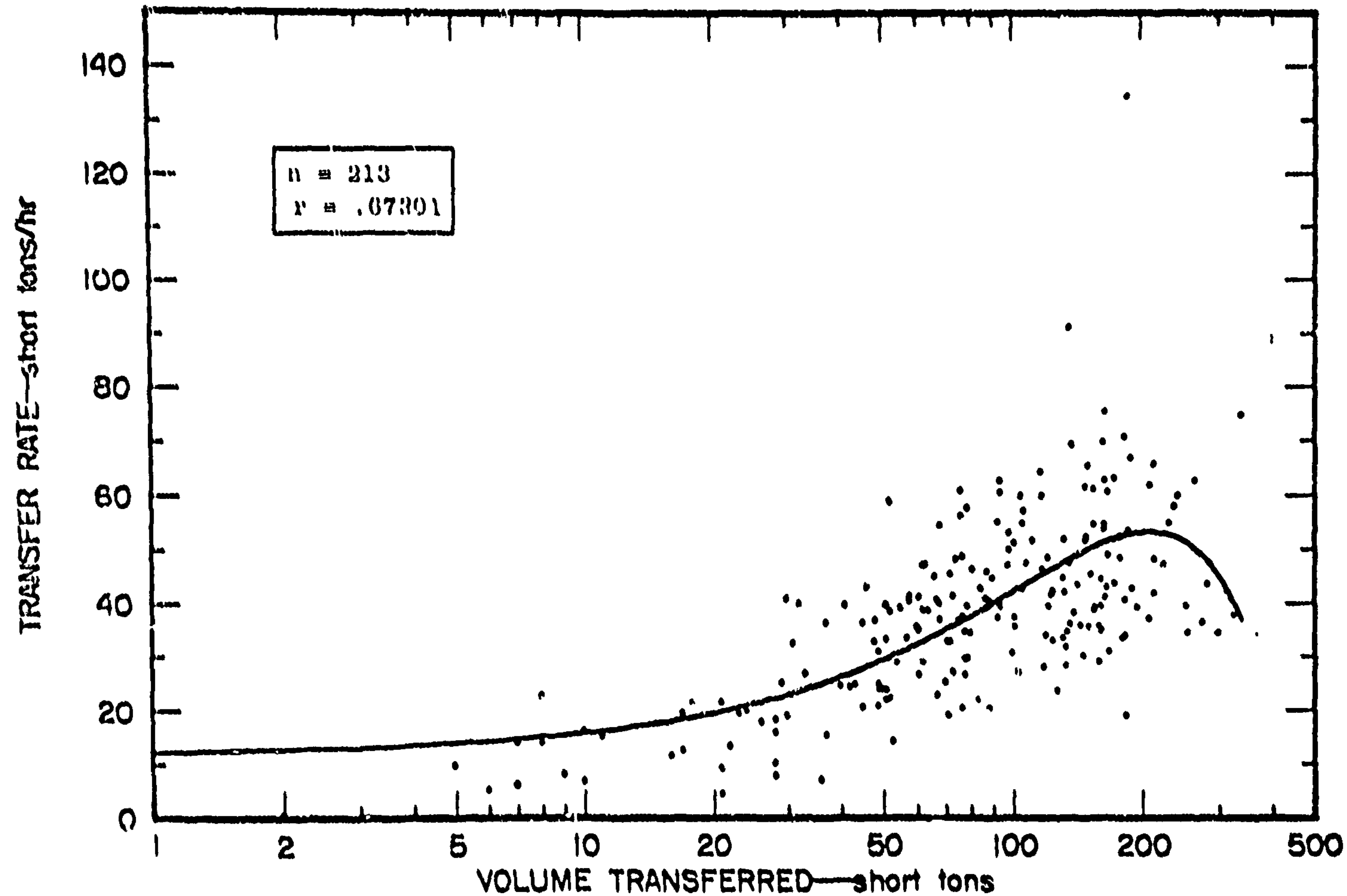


Figure A-7 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CA, CAG, AND CLG TYPES

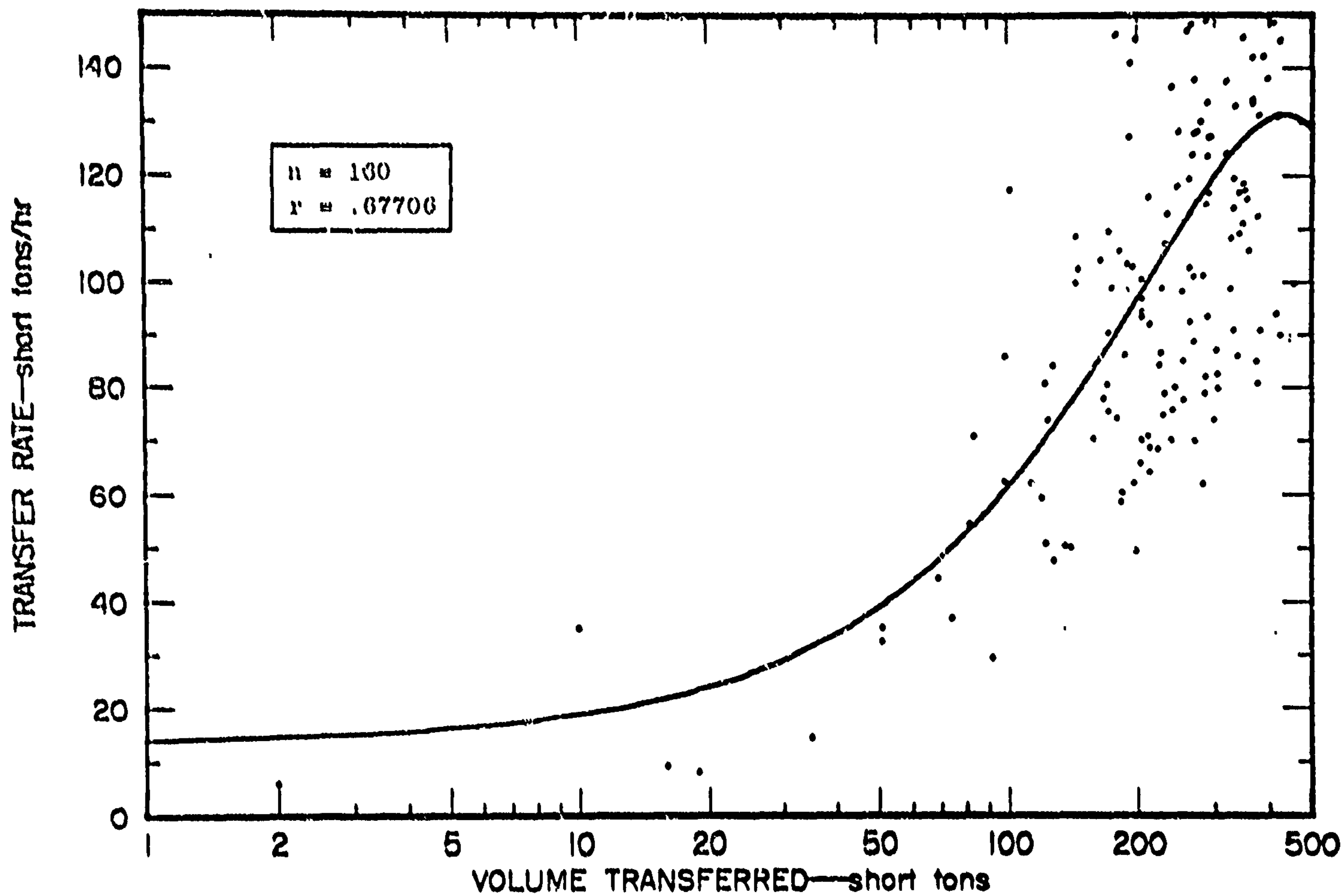


Figure A-8 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVA 14, 19, 31, and 34

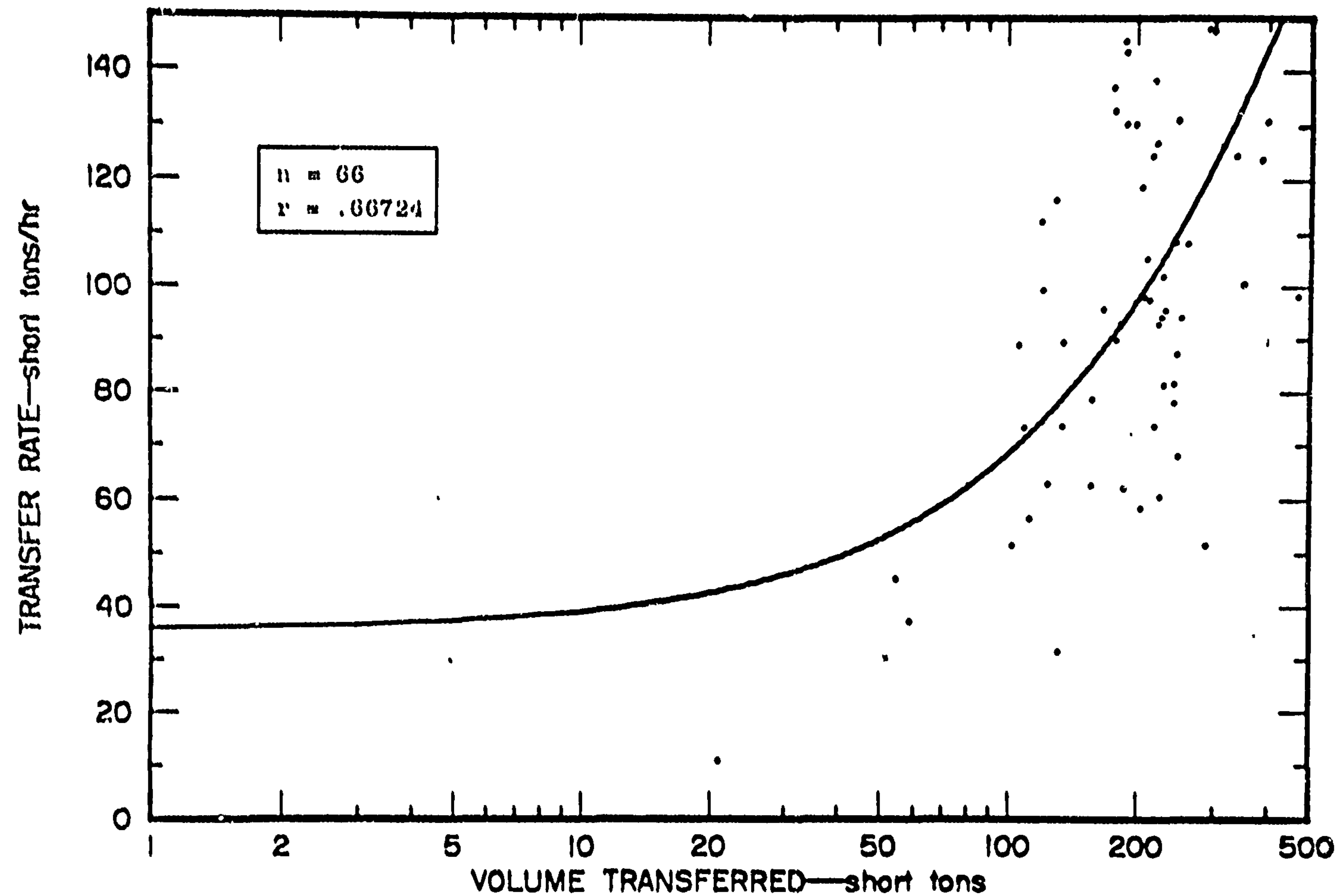


Figure A-9 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVA 41-43

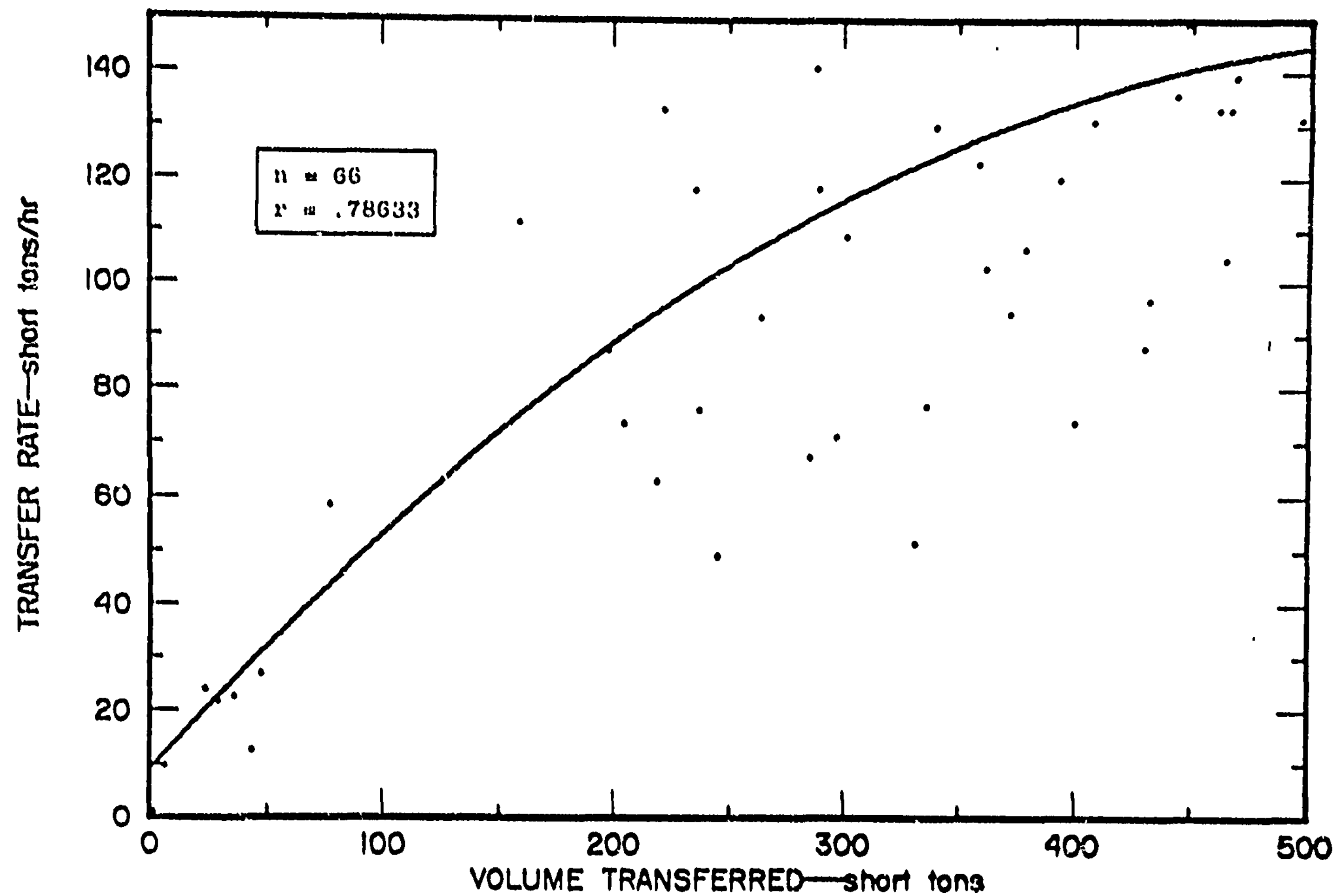


Figure A-10 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVA 59-62

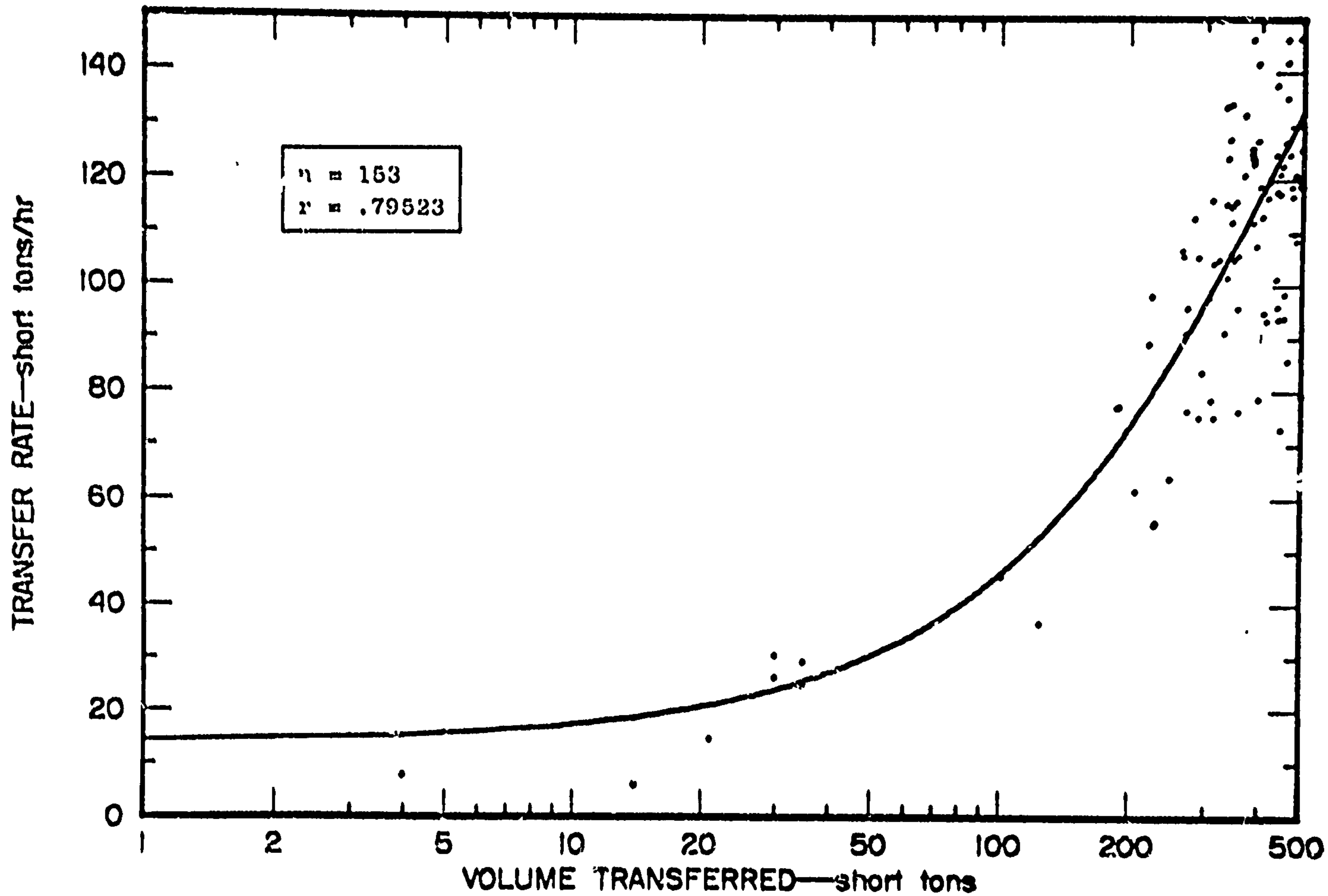


Figure A-11 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVA 63, 64 AND 66

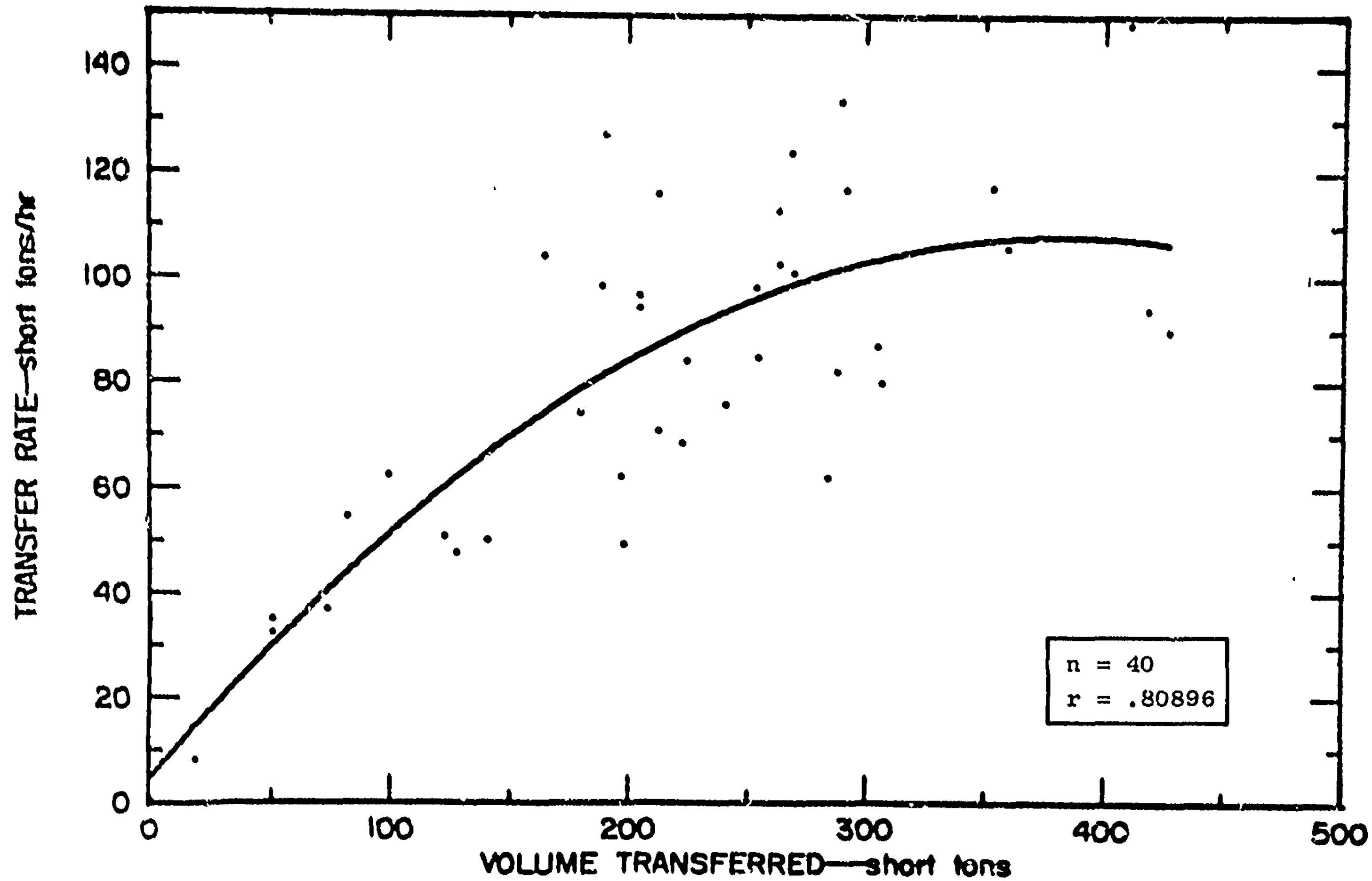


Figure A-12 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVA 14, 19, 31 AND 34 BY AOE TYPE

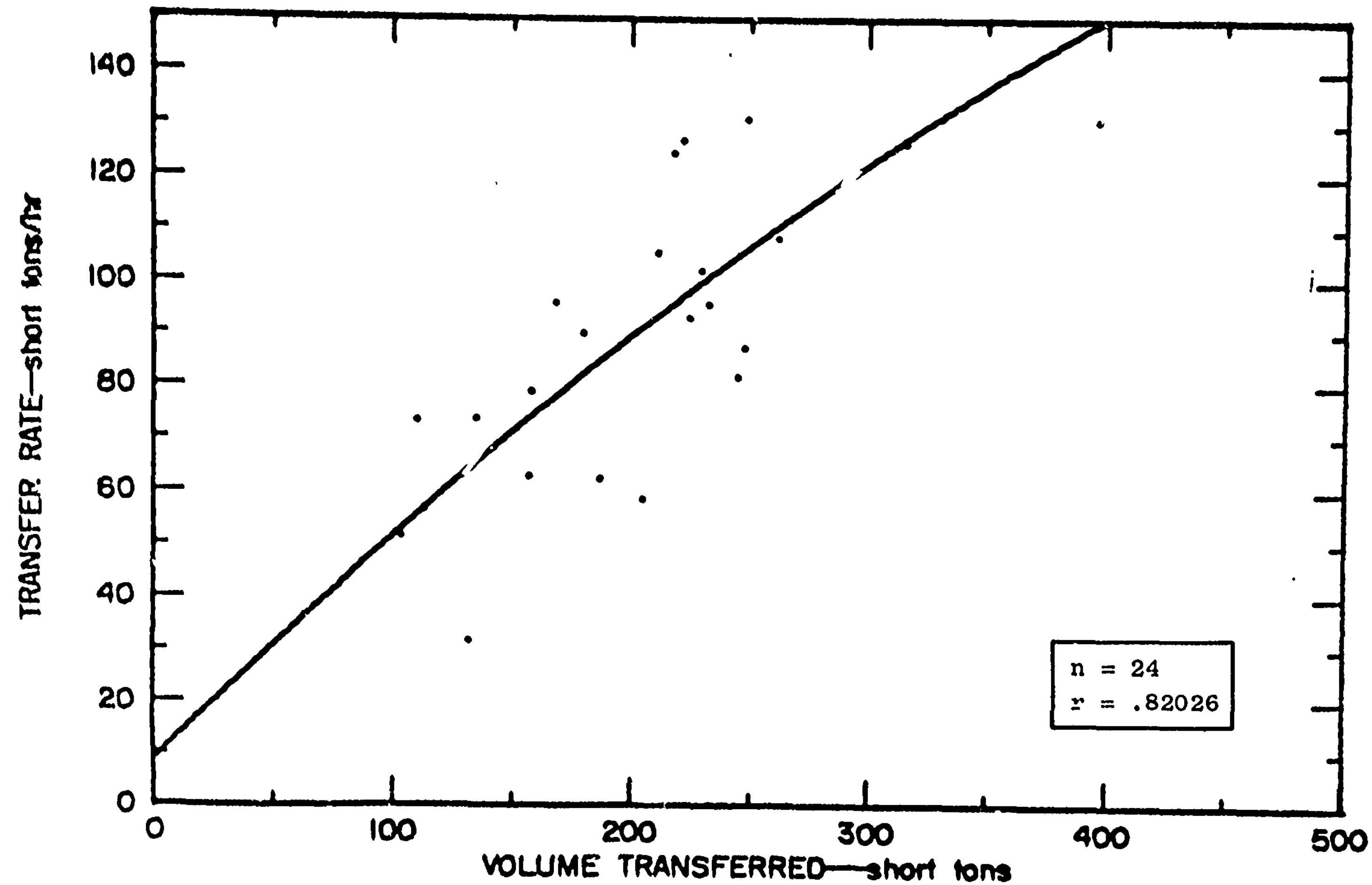


Figure A-13 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVA 41-43 BY AOE TYPE

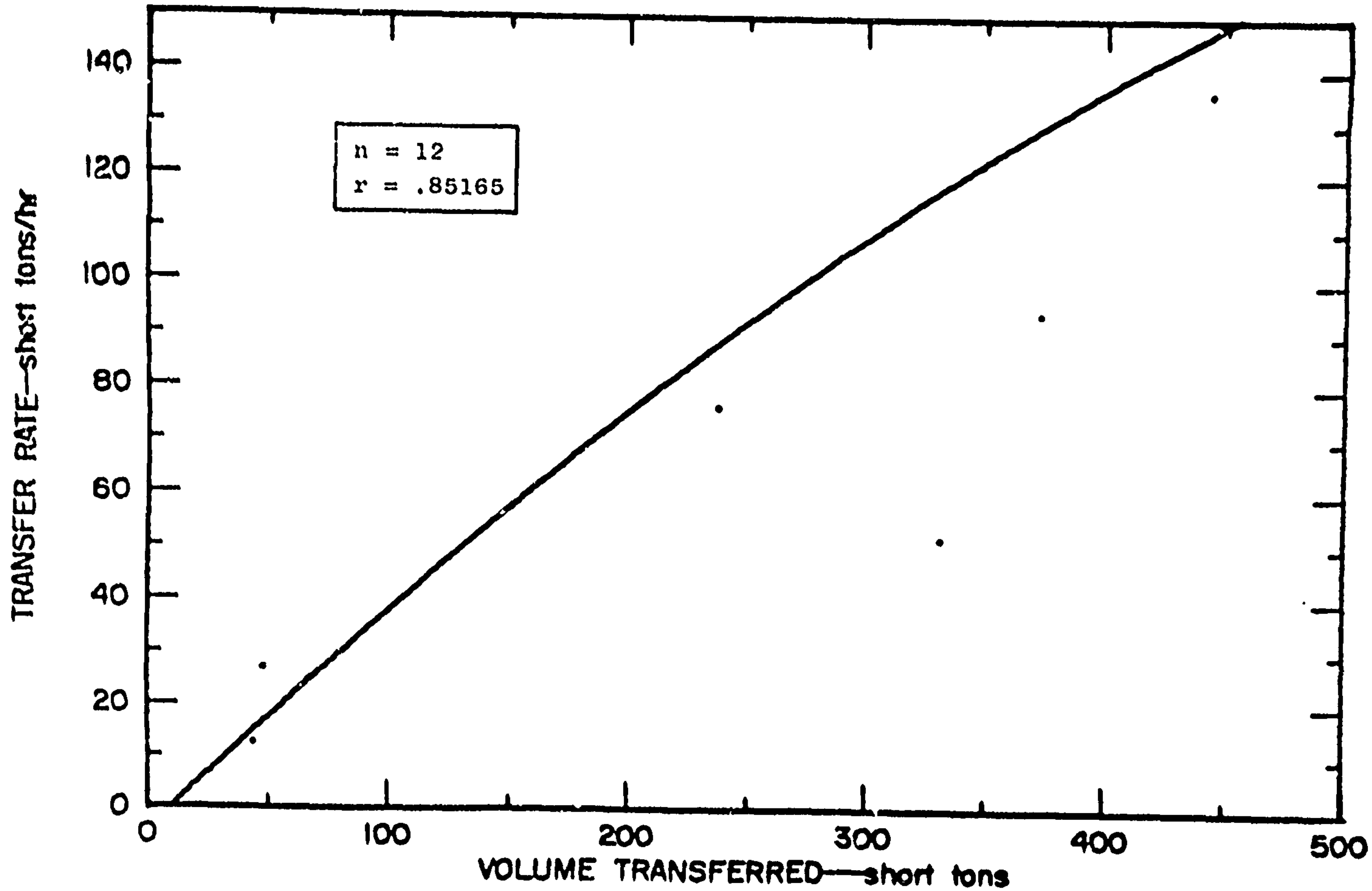


Figure A-14 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVA 59-62 BY AOE TYPE

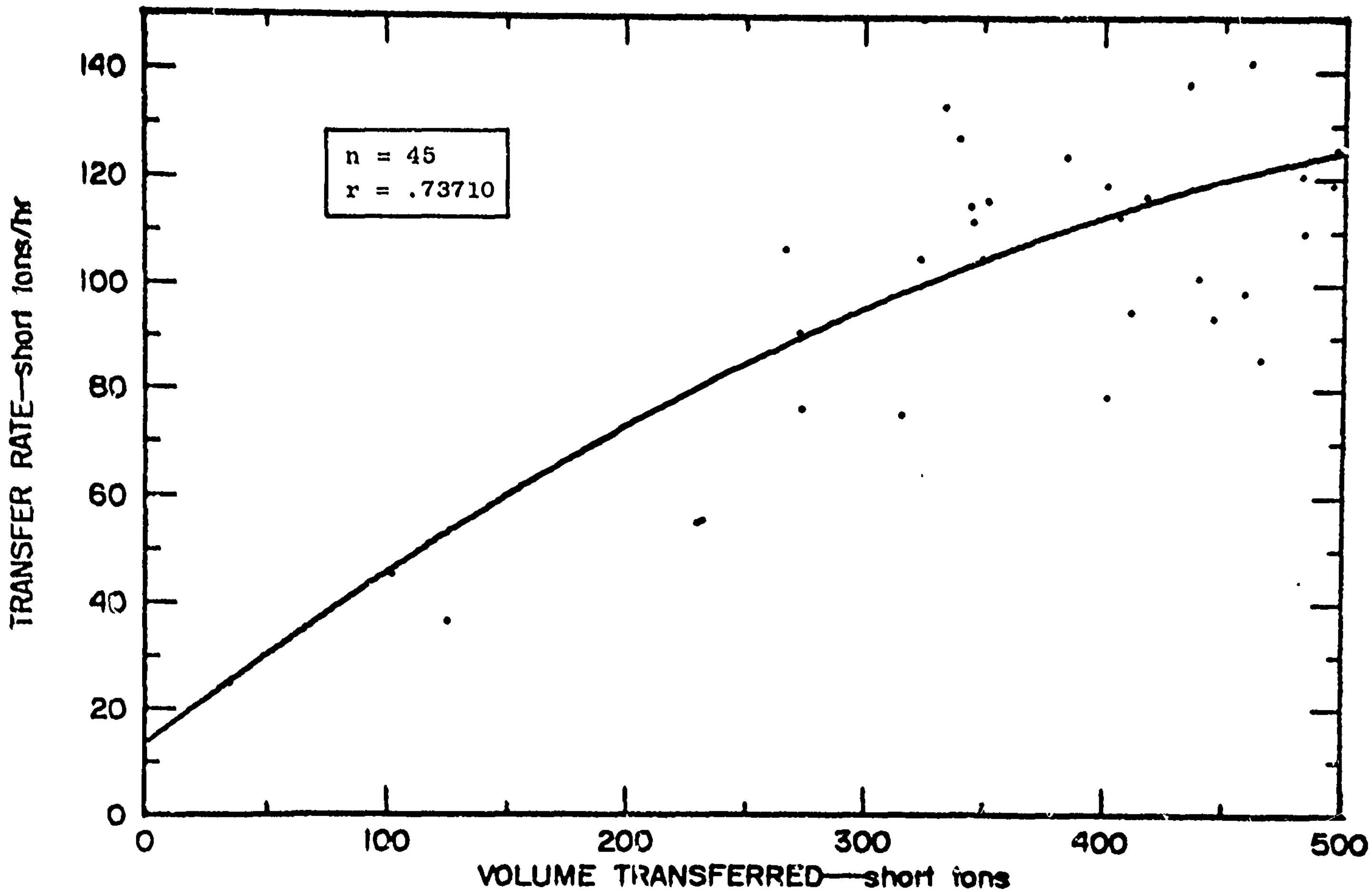


Figure A-15 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLISHMENTS OF CVA 63, 64 AND 66 BY AOE TYPE

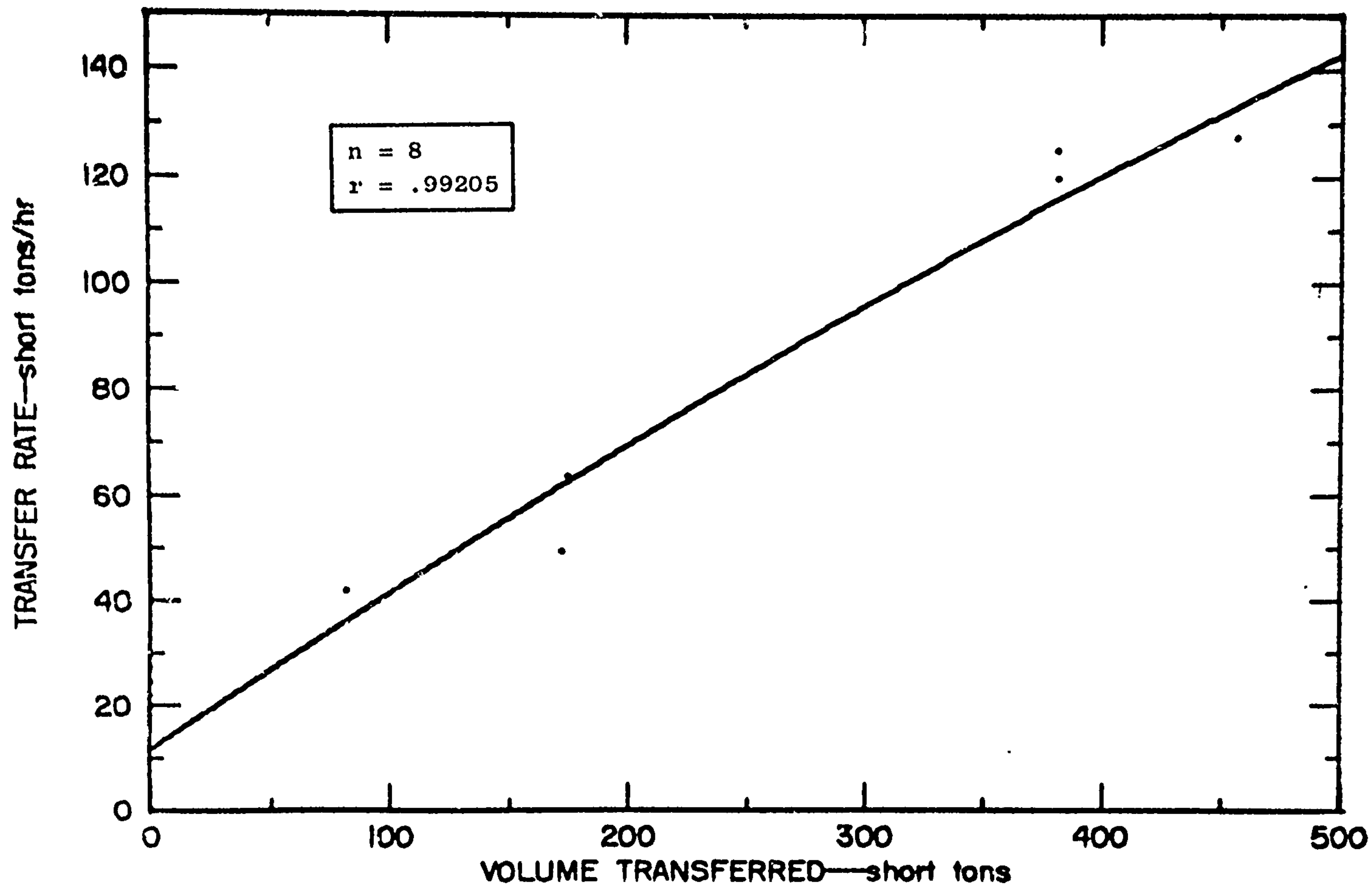


Figure A-16   TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CVAN 65 BY AOE TYPE

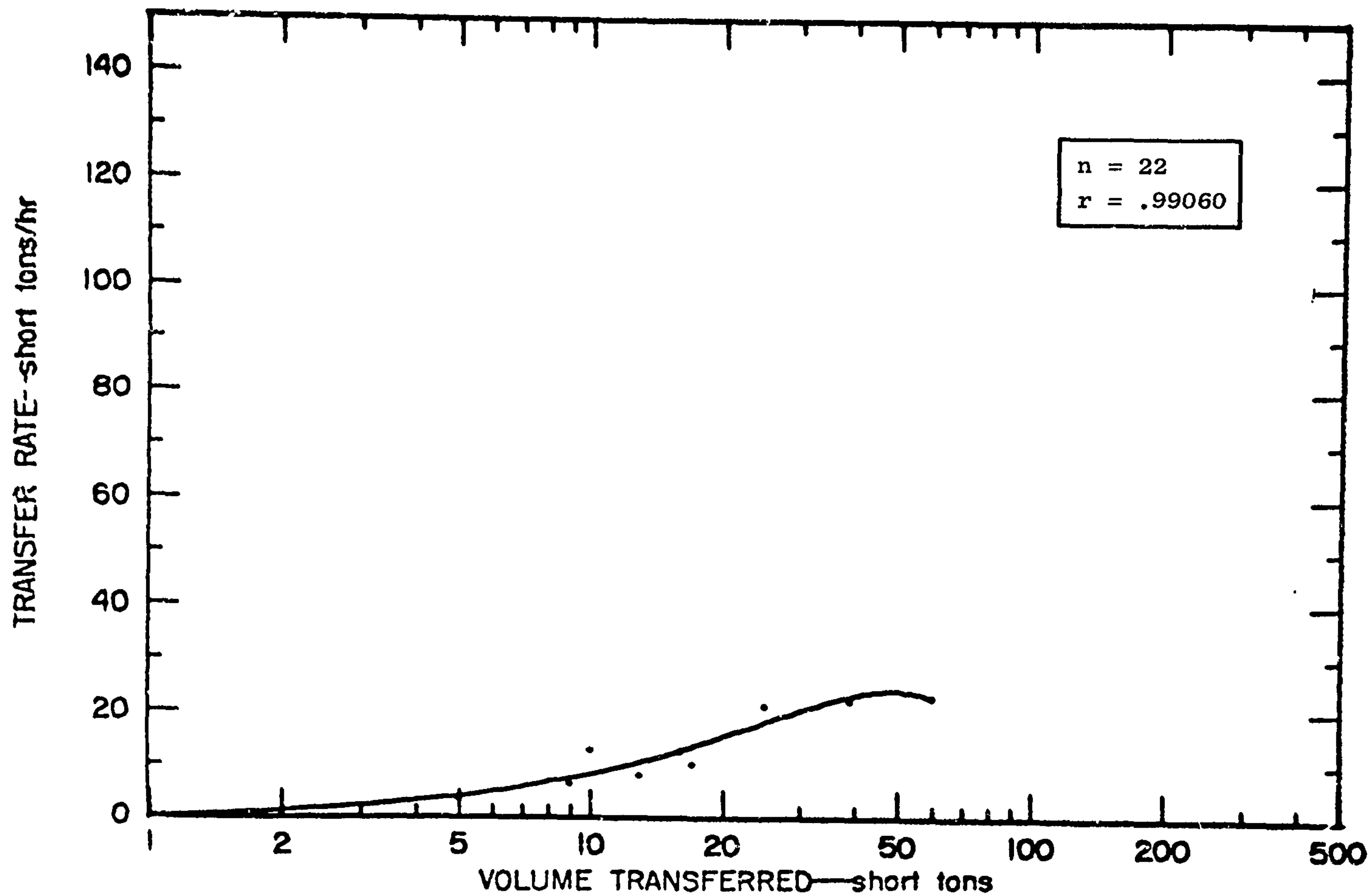


Figure A-17 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DD CLASSES OTHER THAN FRAM MK I, FRAM MK II, 931 AND 945 BY AOE TYPE

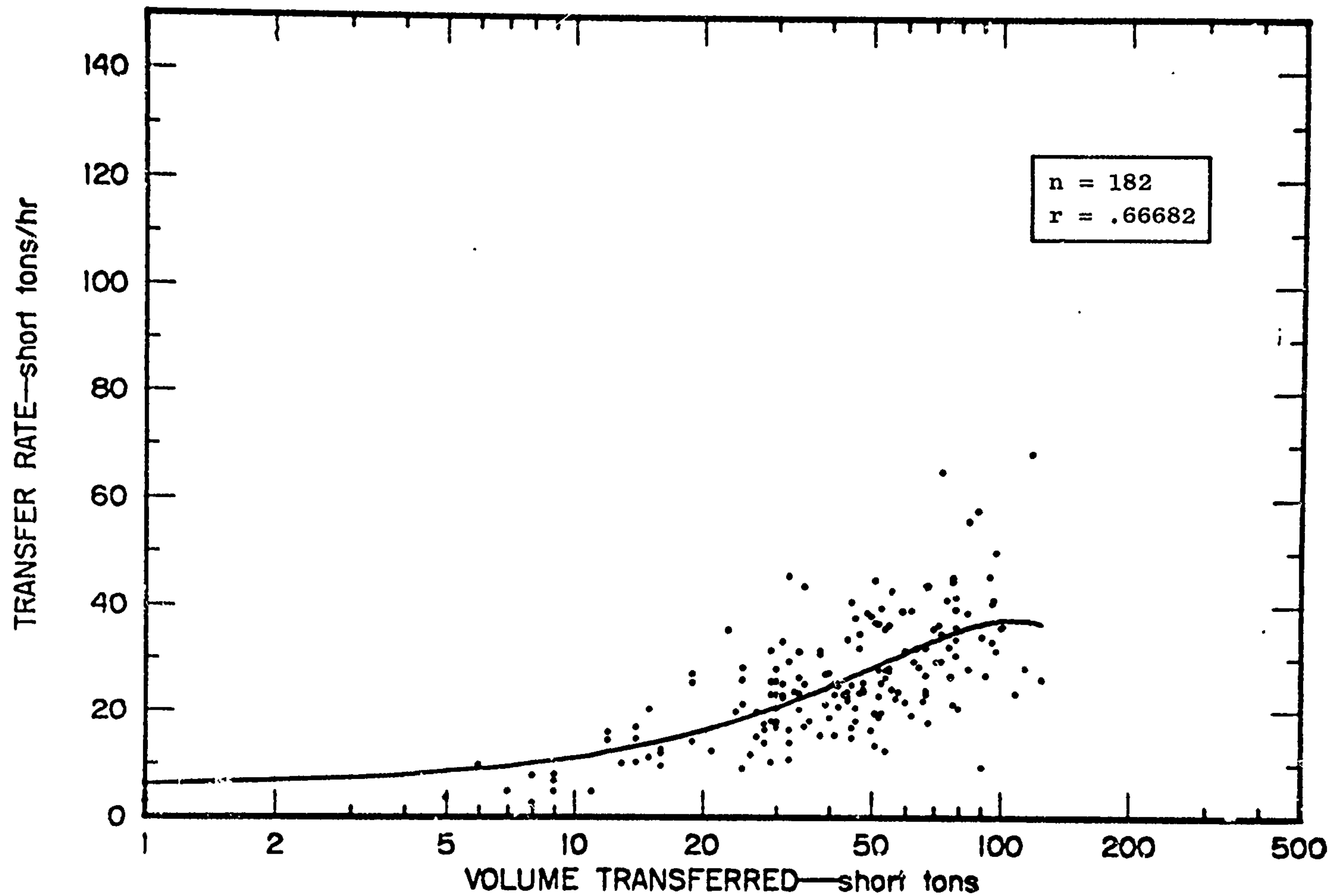


Figure A-18 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DD 931 AND 945 CLASSES

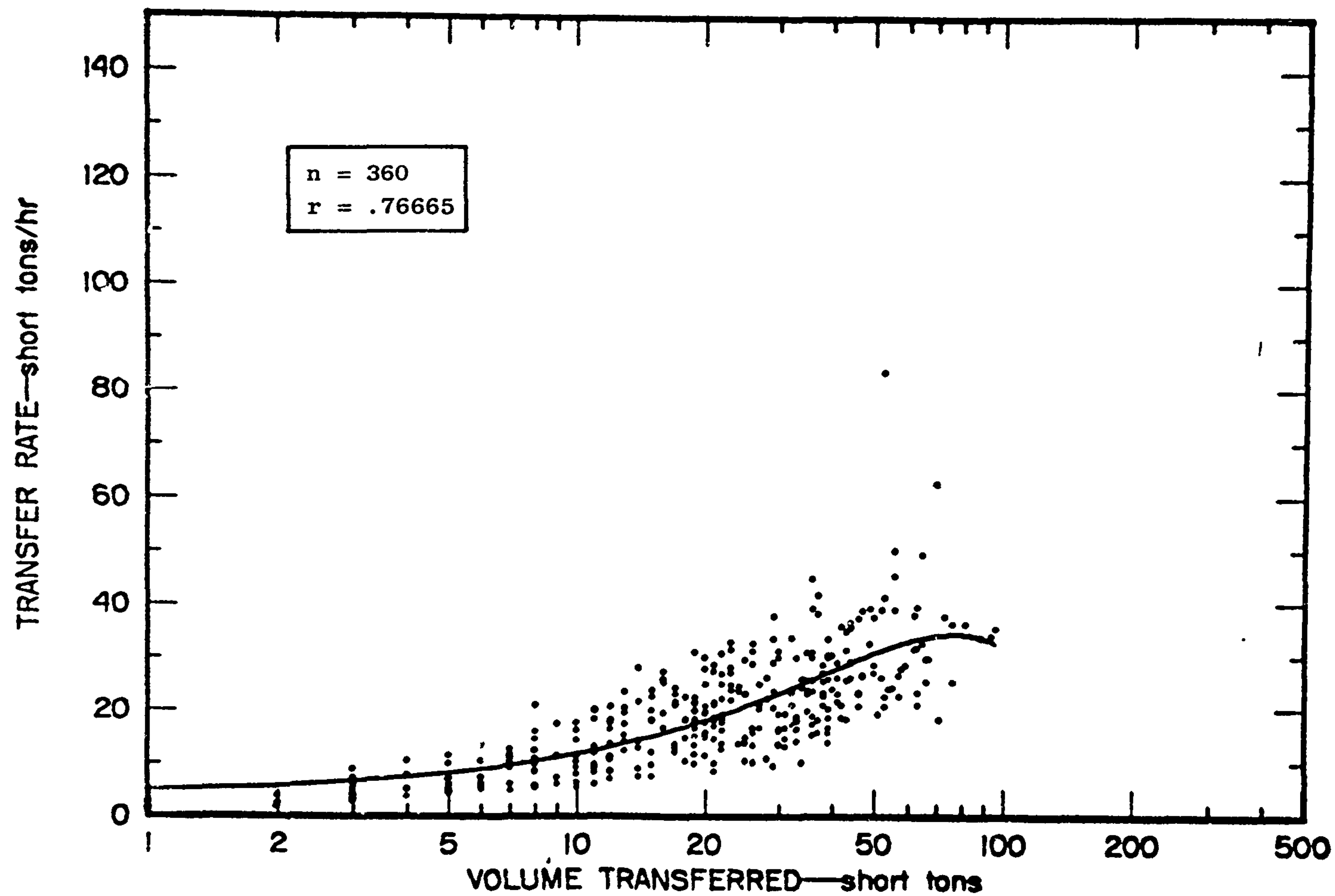


Figure A-19 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DD FRAM MK I CLASS

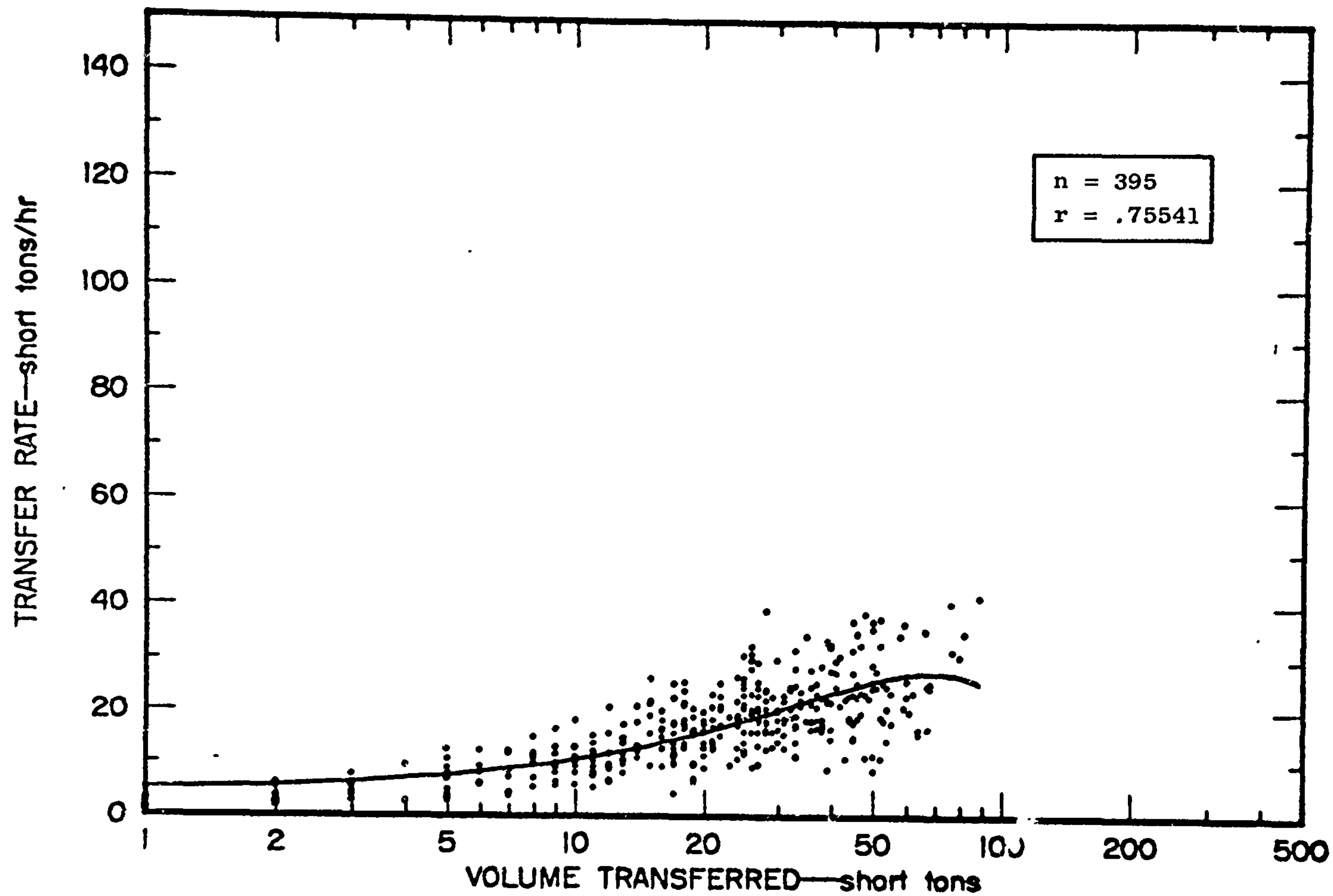


Figure A-20 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DD FRAM MK II CLASS

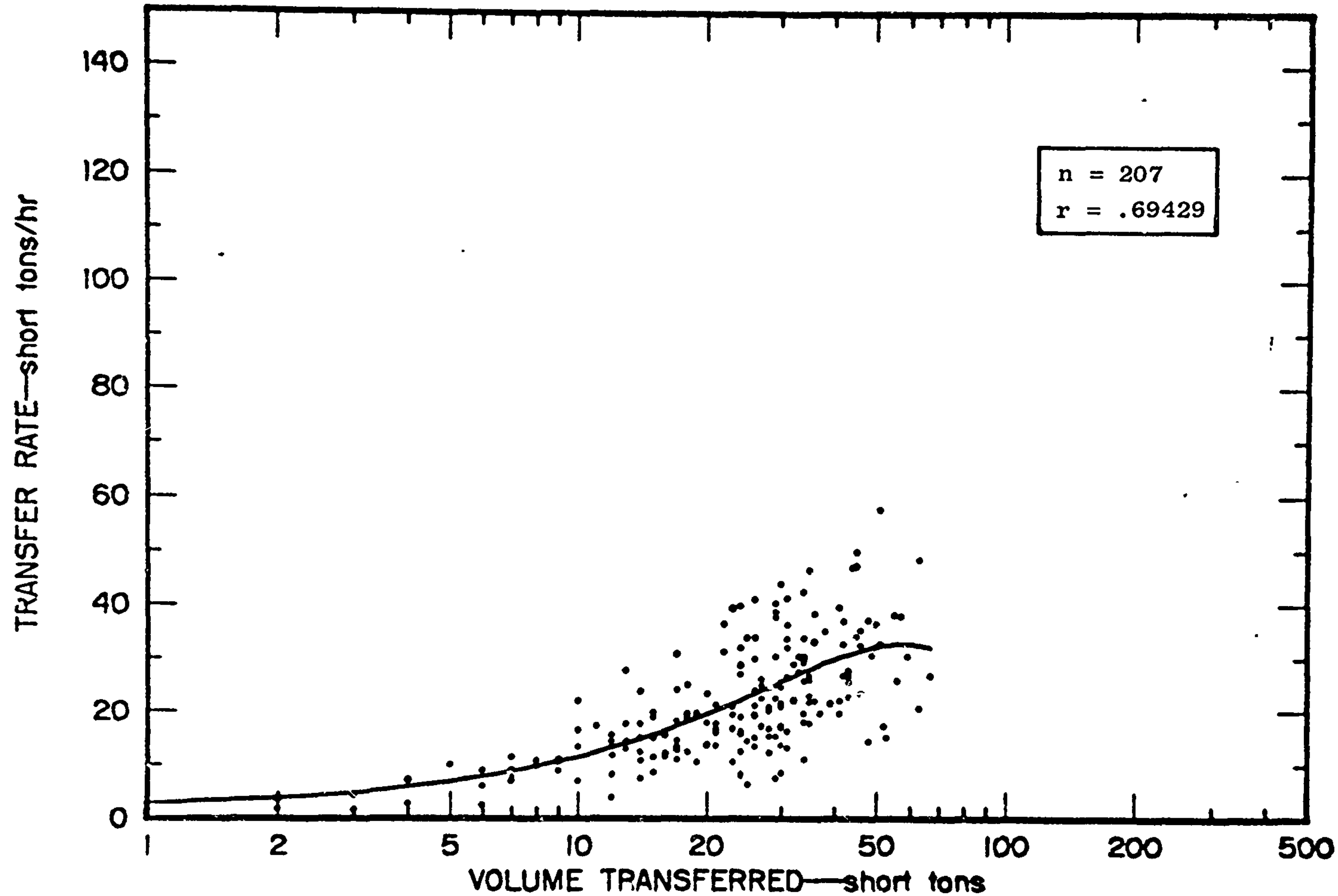


Figure A-21 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DDG TYPE

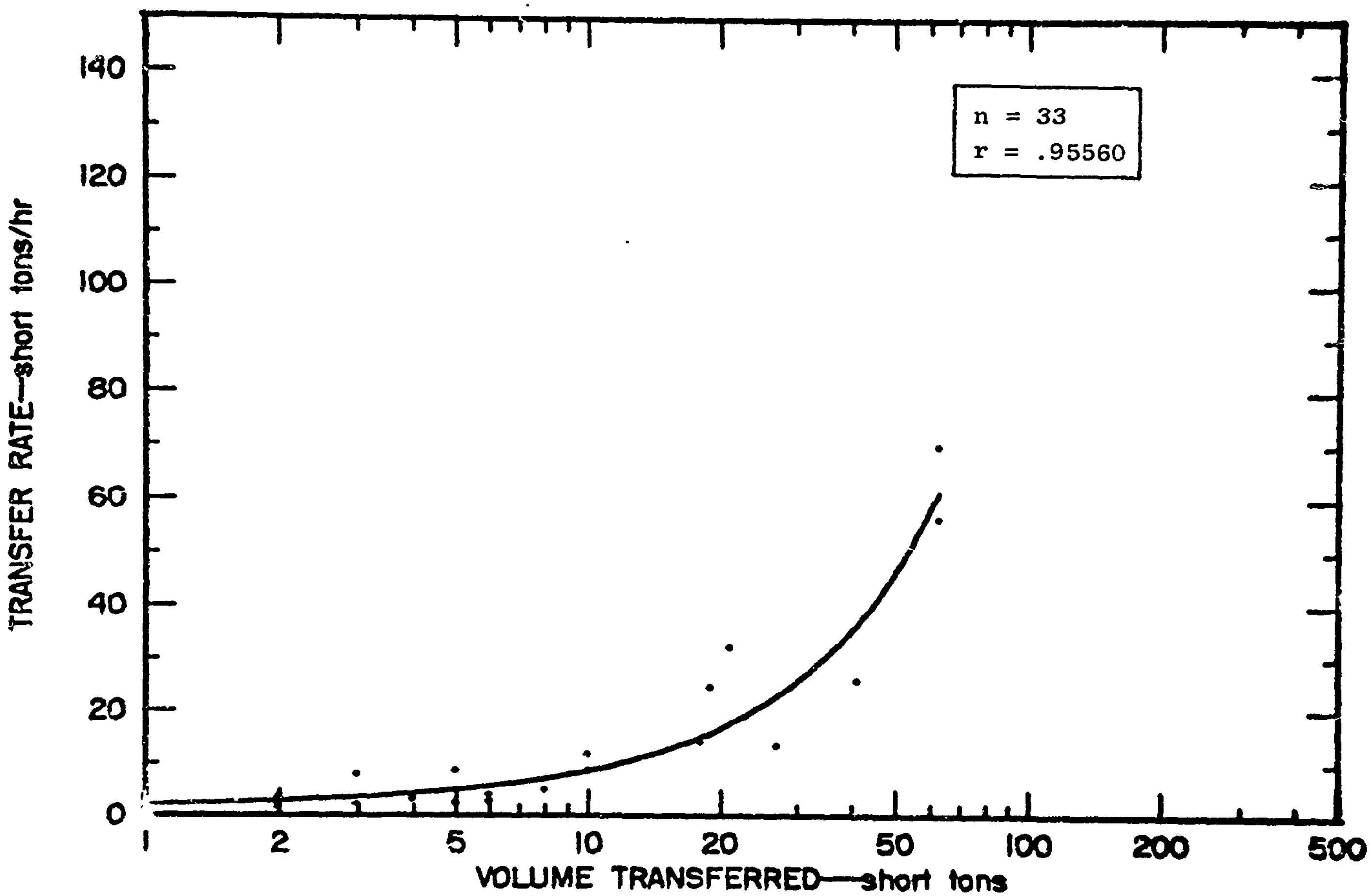


Figure A-22 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DL, DLG AND DLGN TYPES

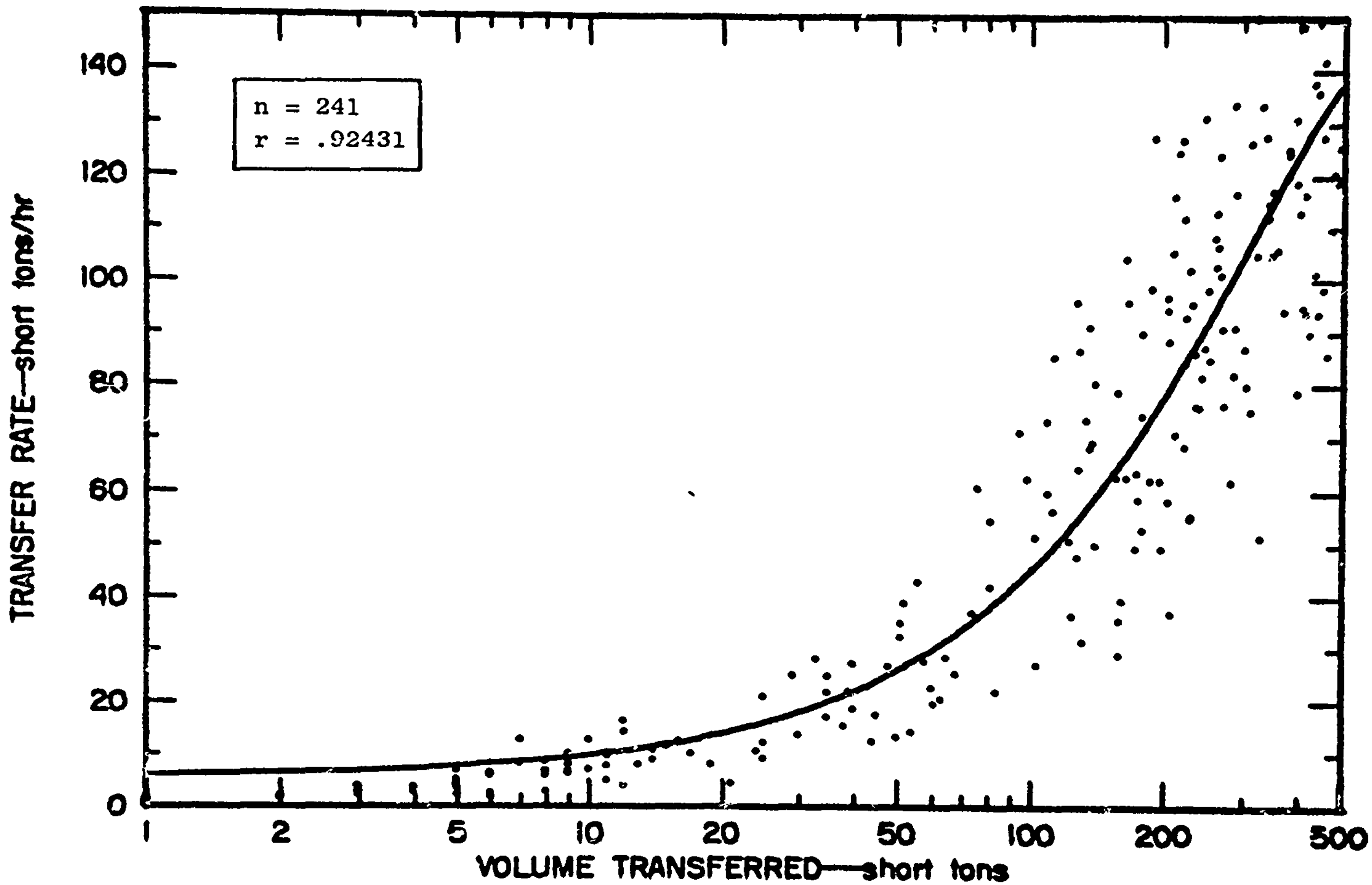


Figure A-23 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS BY AOE TYPE

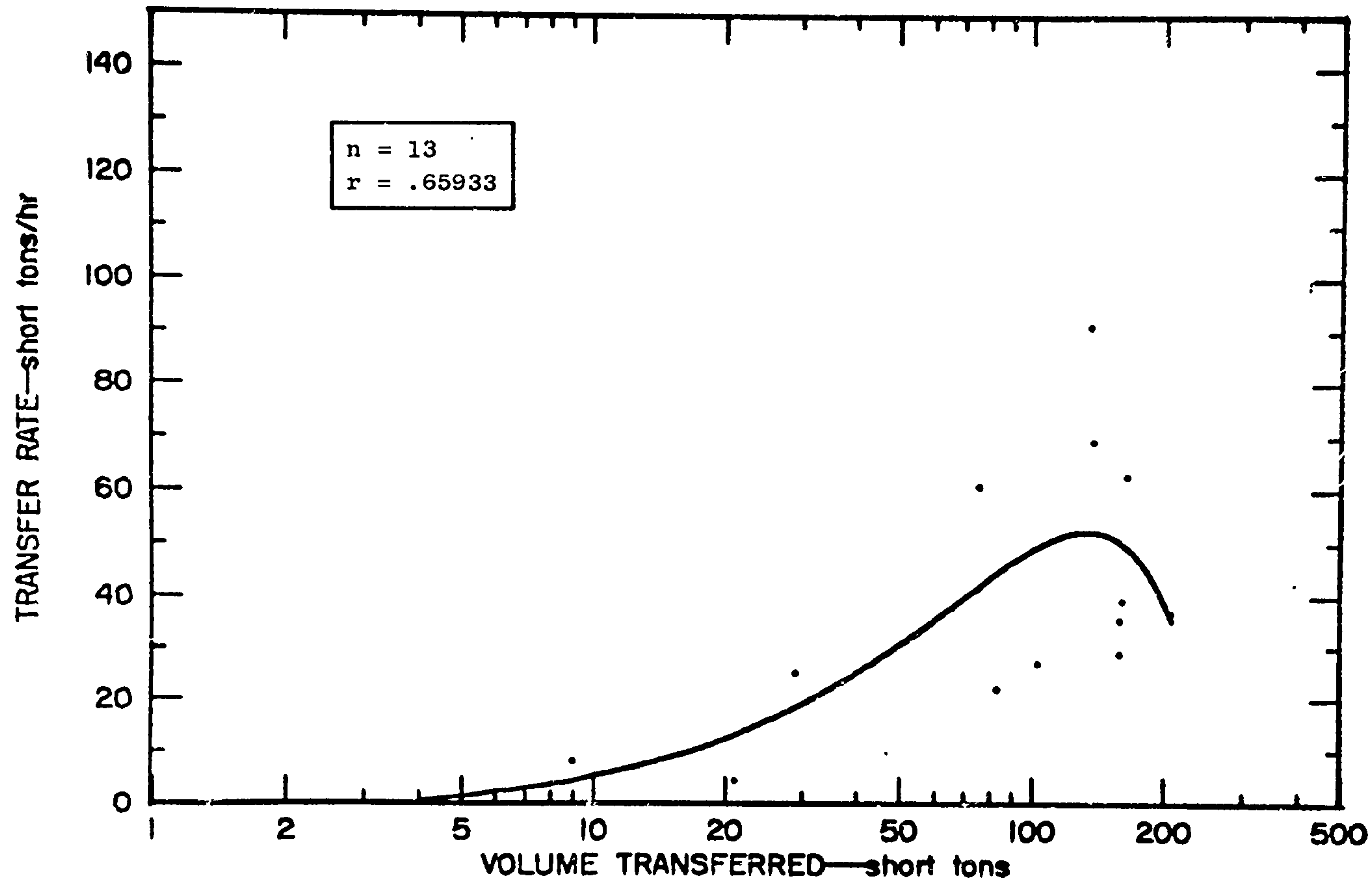


Figure A-24 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF CA, CAG AND CLG TYPES BY AOE TYPE

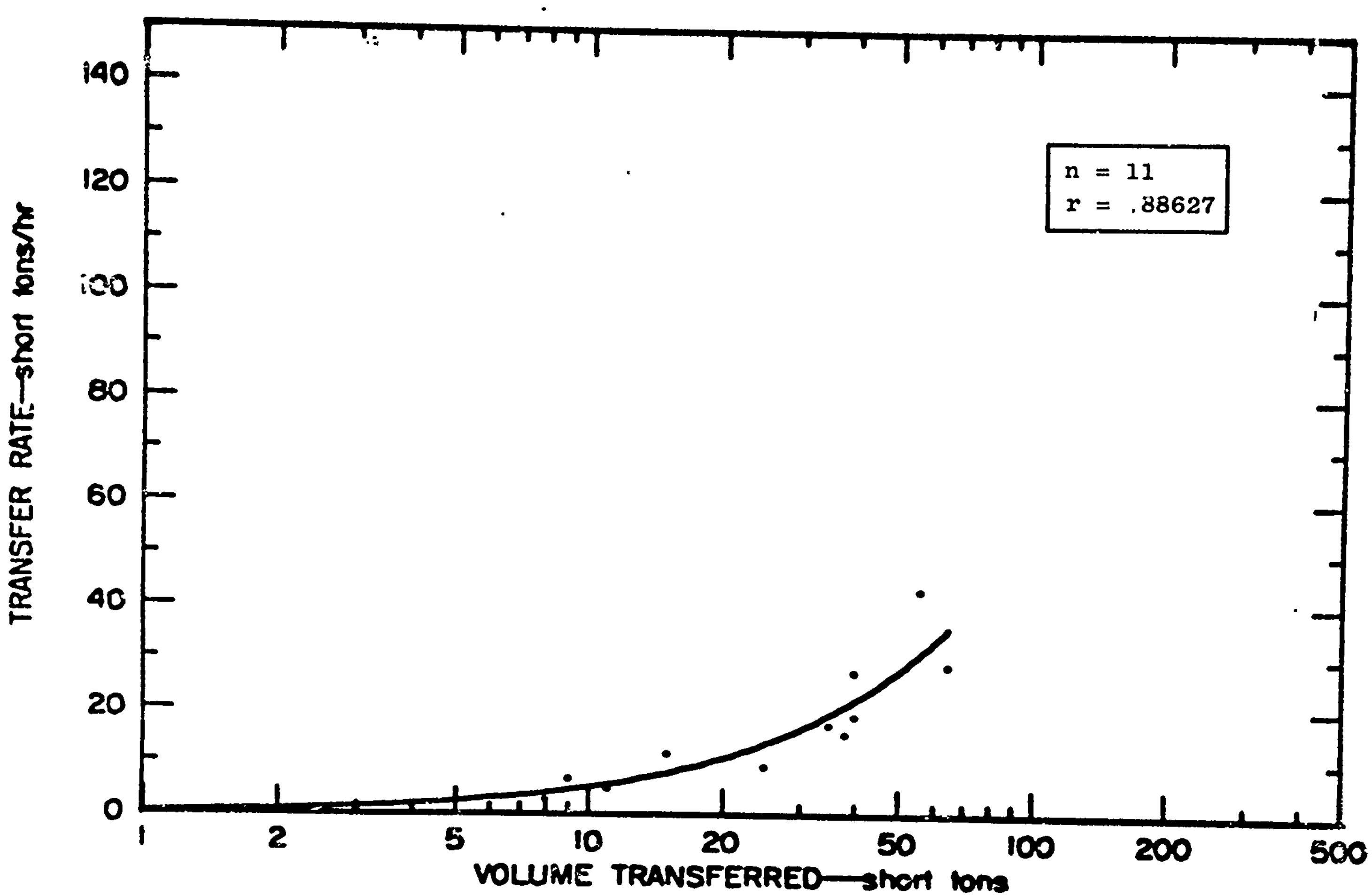


Figure A-25 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DD 931 AND 945 CLASSES BY AOE TYPE

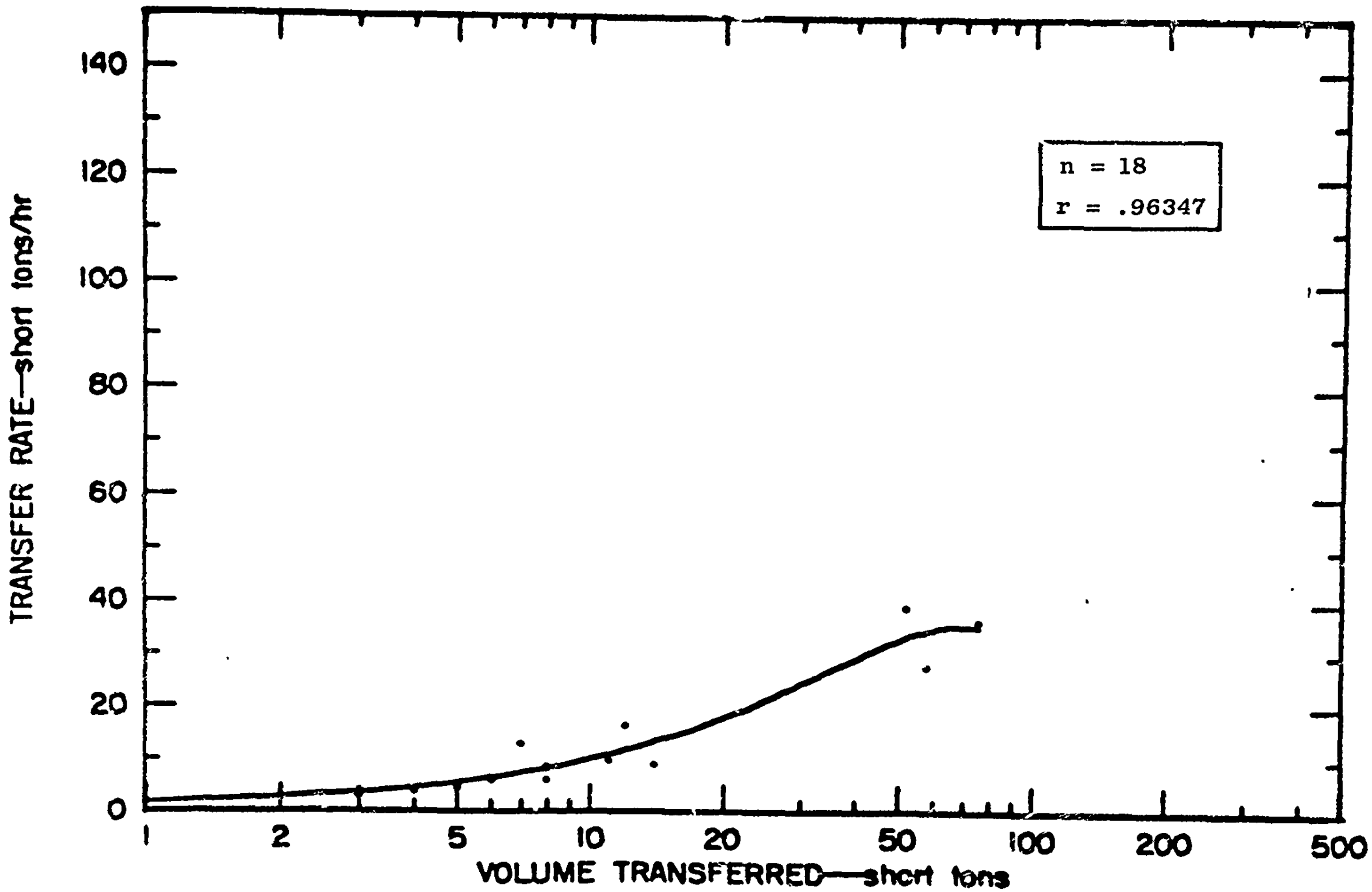


Figure A-26 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DD FRAM MK I CLASS BY AOE TYPE

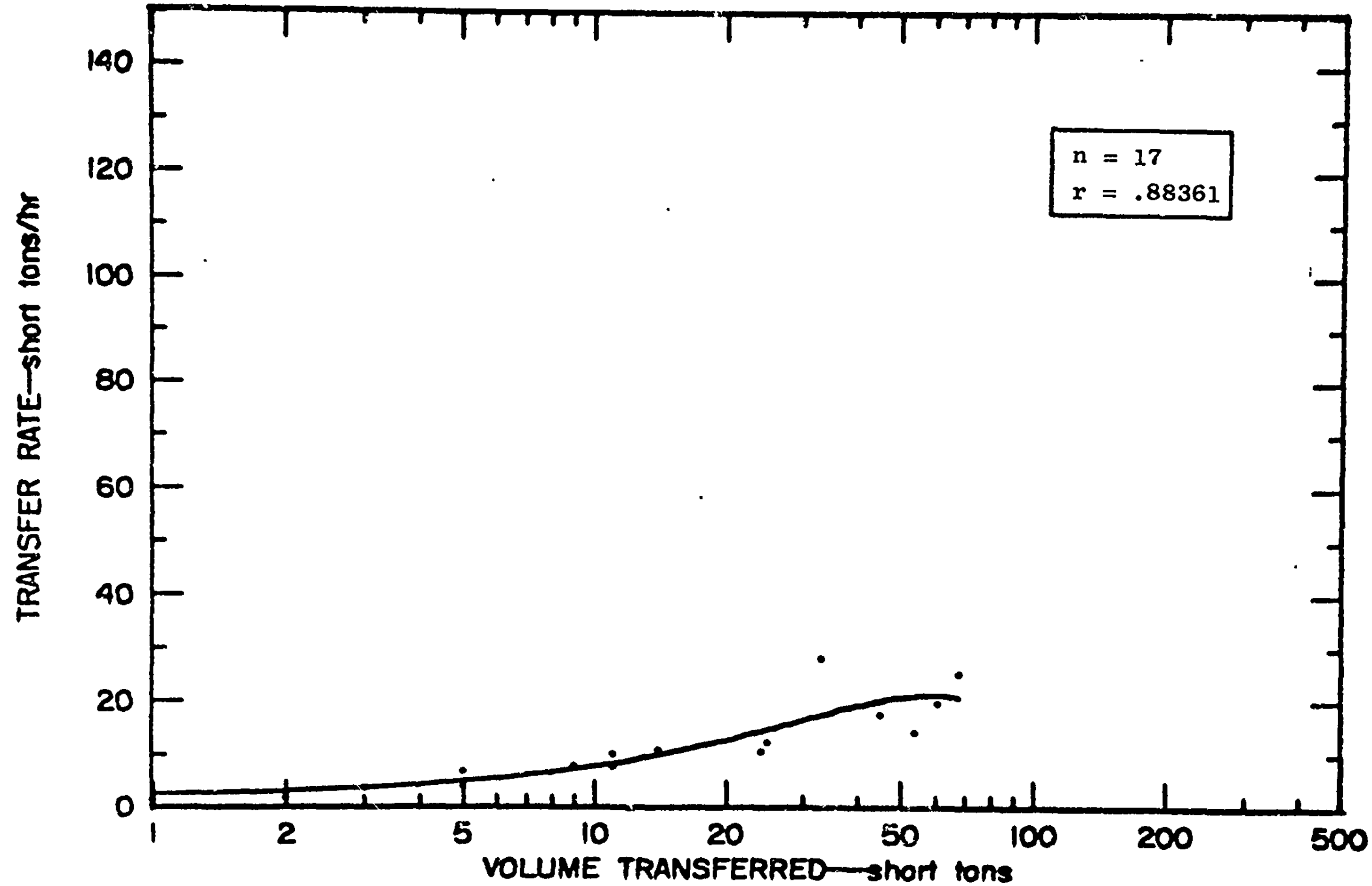


Figure A-27 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DD FRAM MK II CLASS BY AOE TYPE

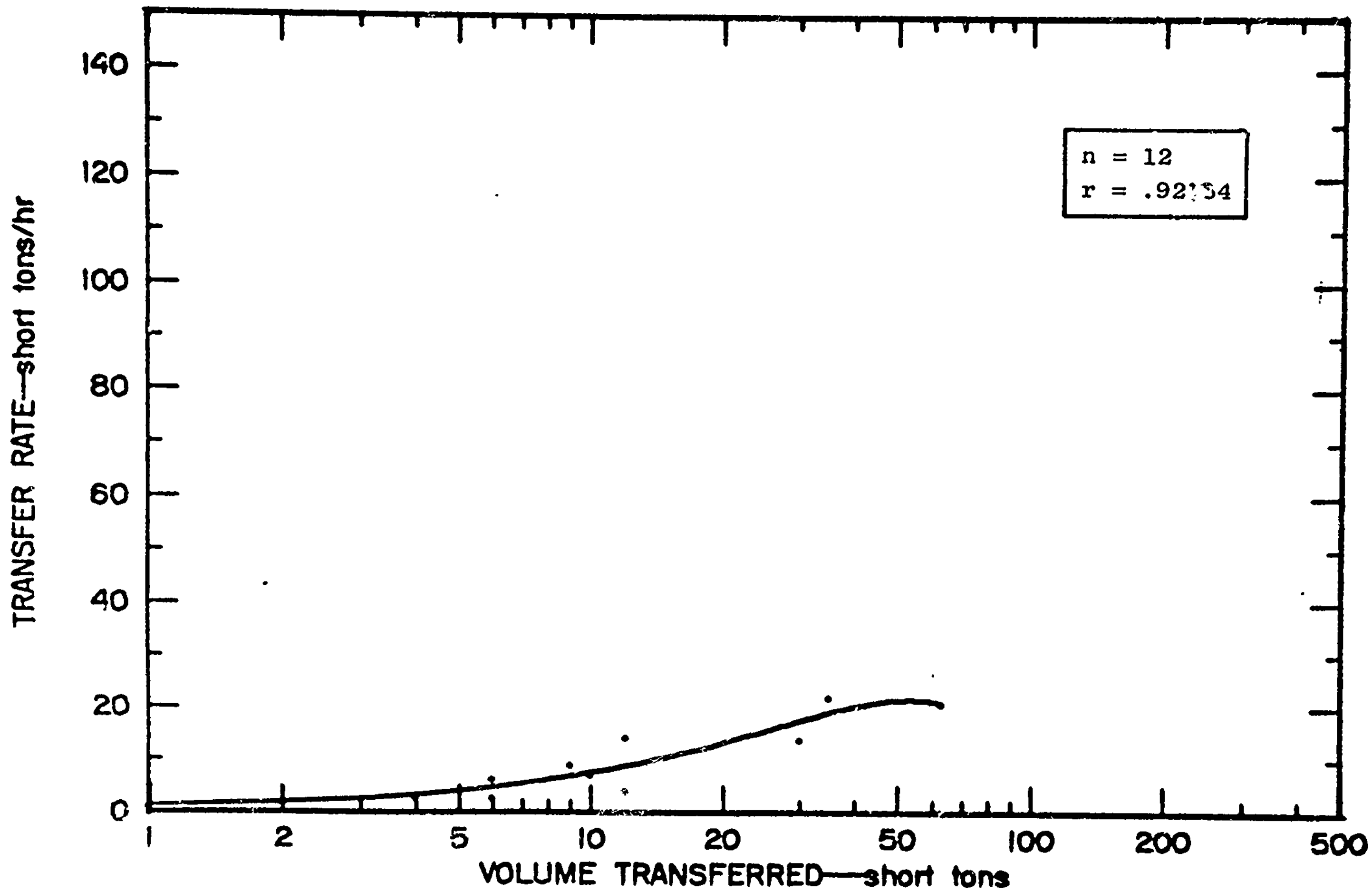


Figure A-28 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DDG TYPE BY AOE TYPE

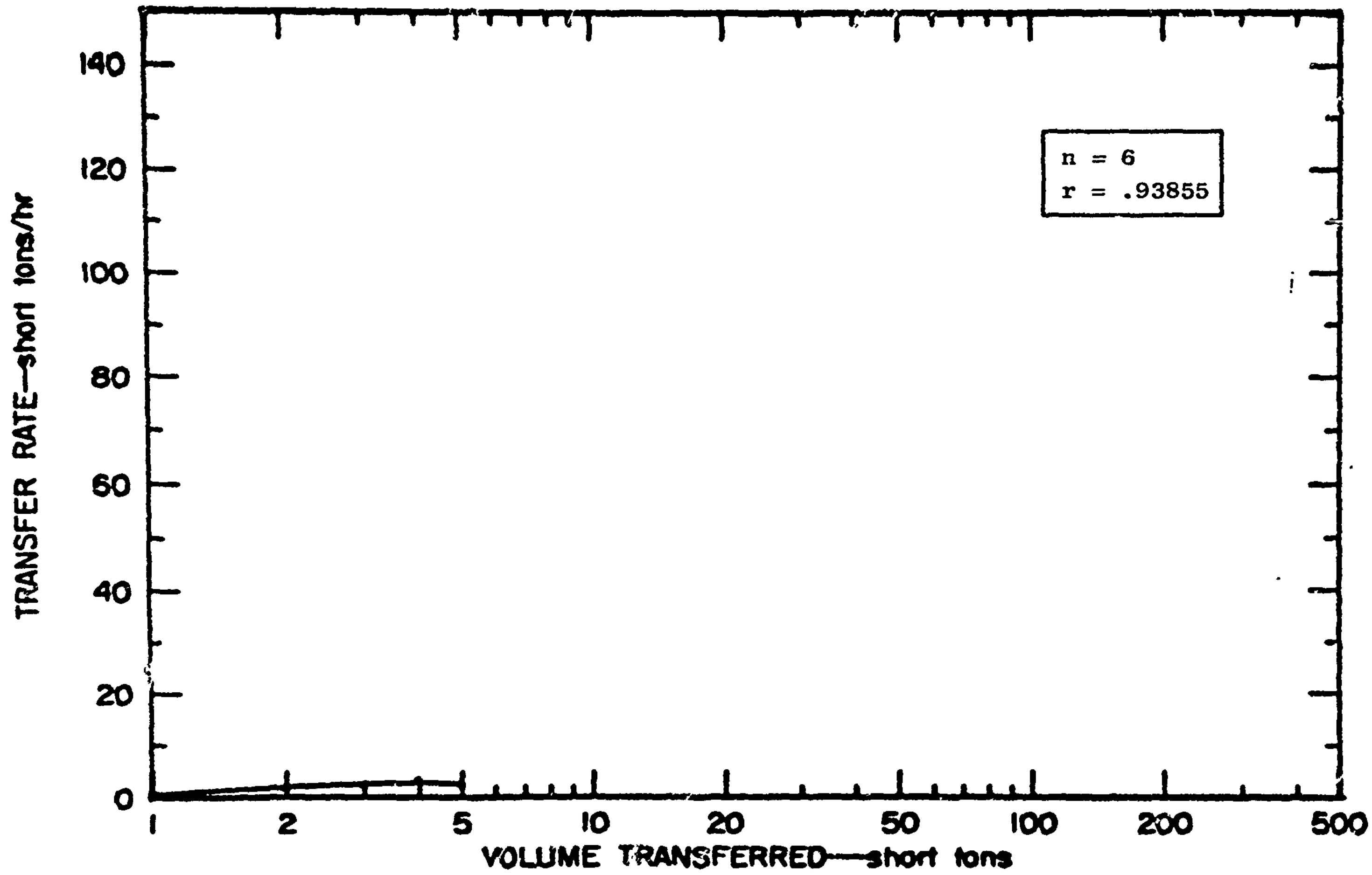


Figure A-29 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ORDNANCE REPLENISHMENTS OF DLG, DLGN, AND DL TYPES BY AOE TYPE

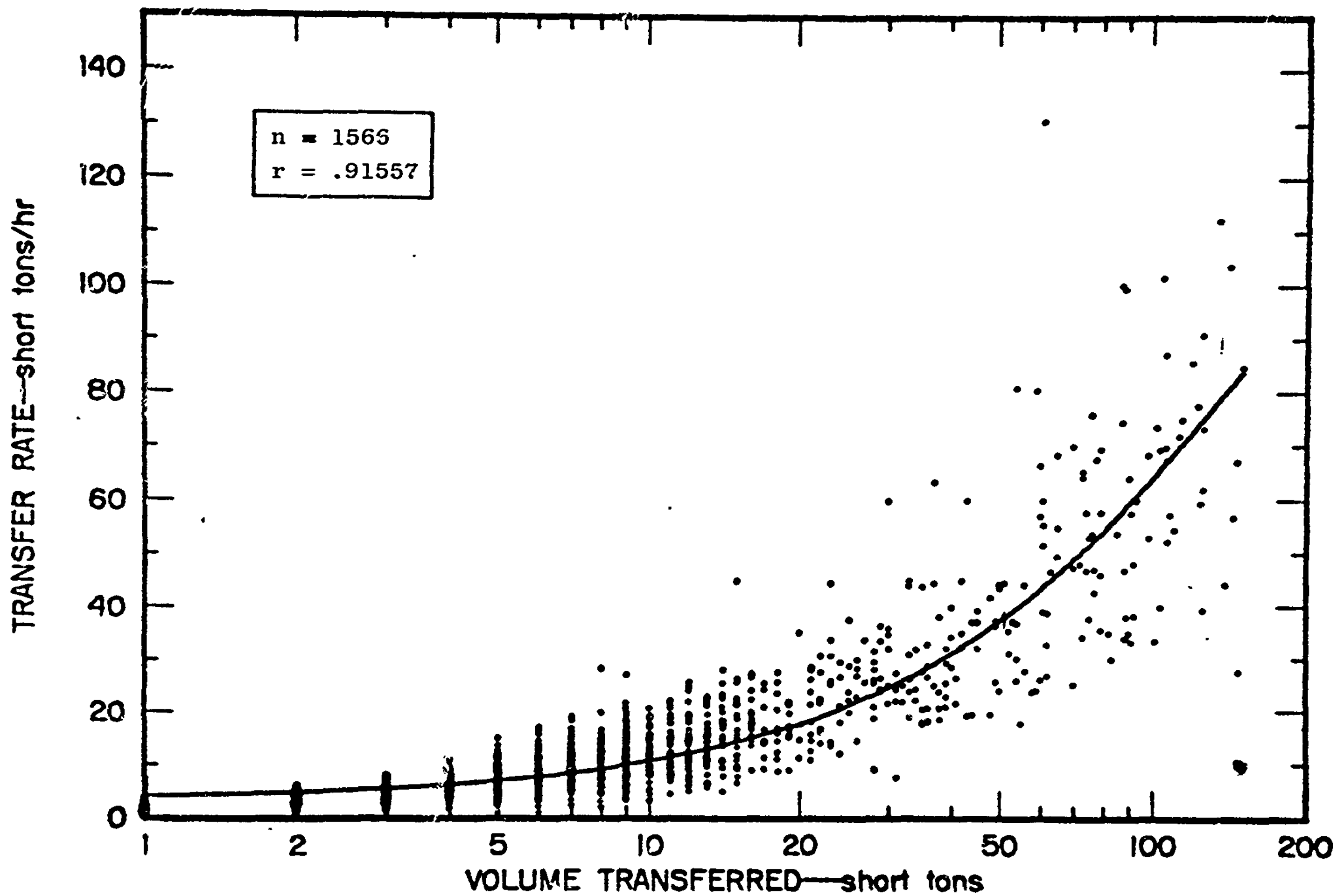


Figure A-30 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ALL PROVISIONS REPLENISHMENTS

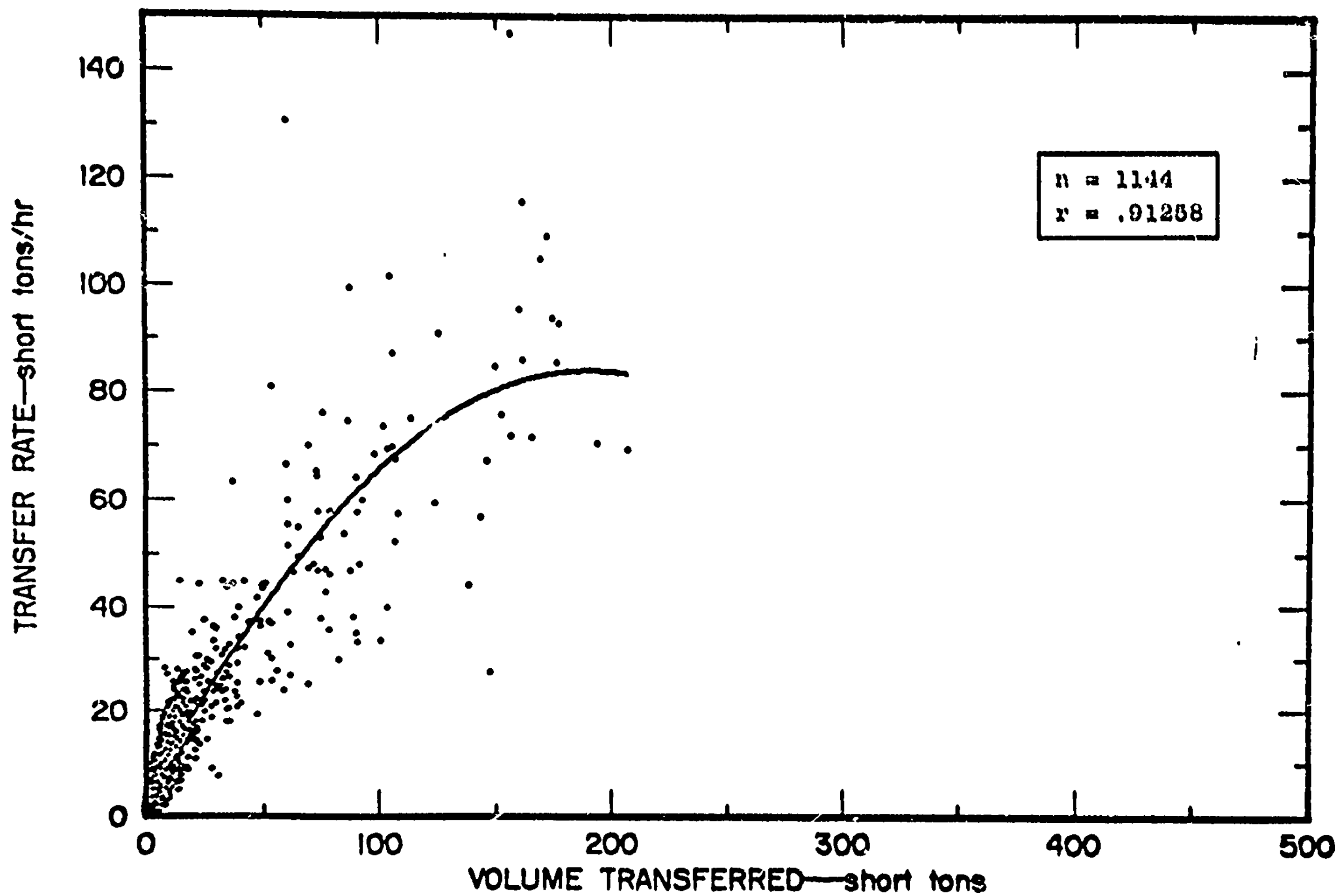


Figure A-31 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR DAYTIME PROVISIONS REPLENISHMENTS

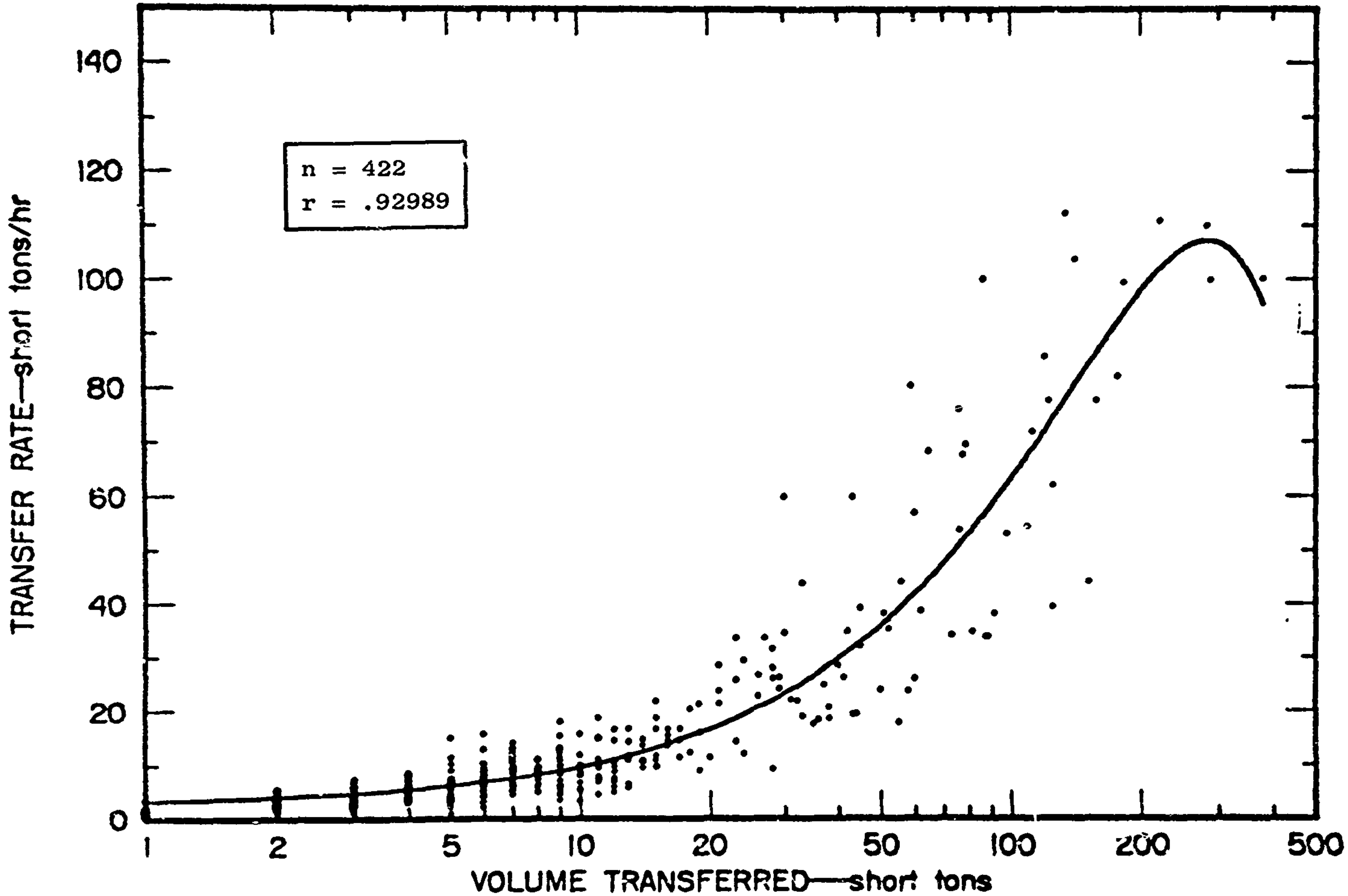


Figure A-32 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NIGHTTIME PROVISIONS REPLENISHMENTS

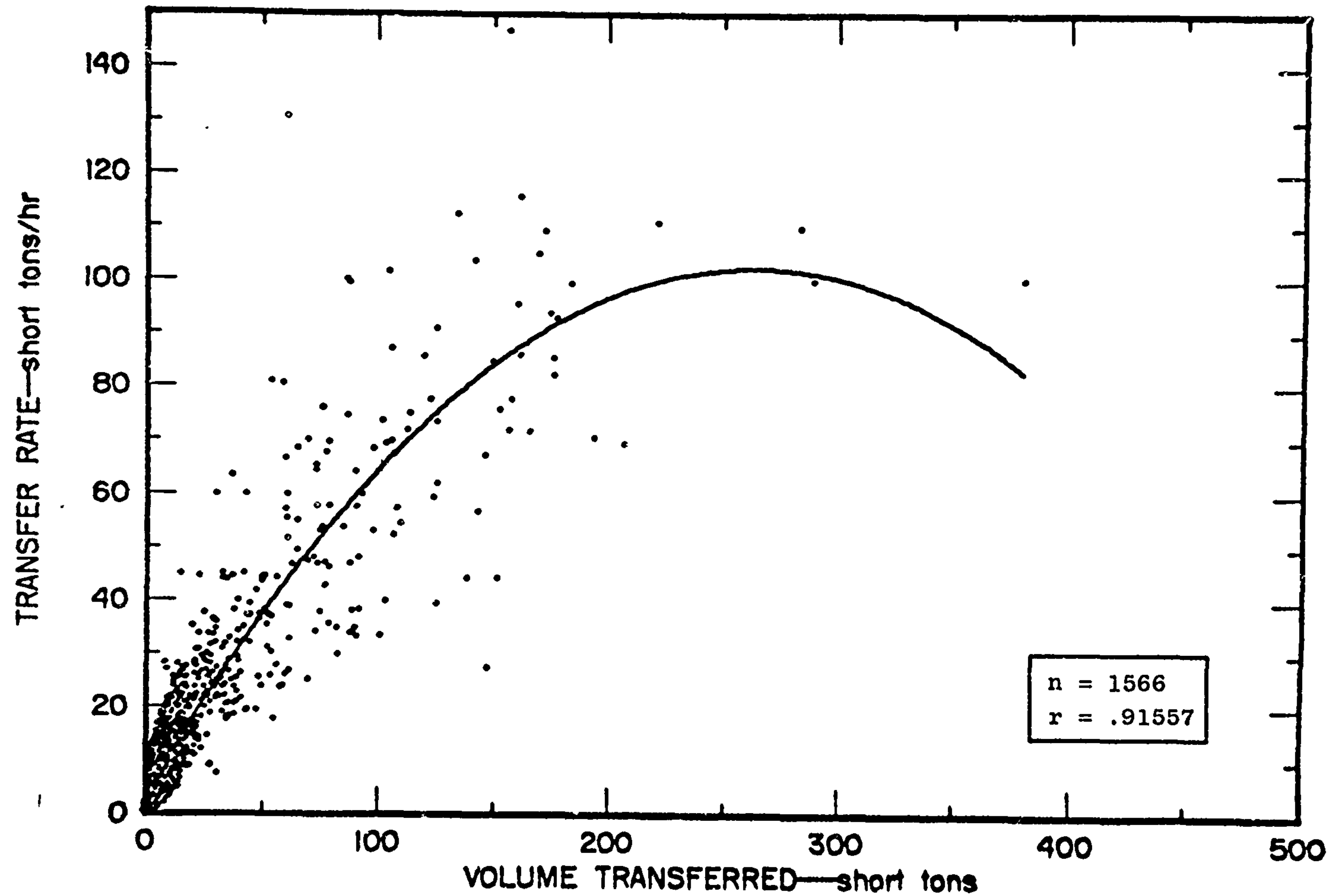


Figure A-33 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS IN WESTPAC

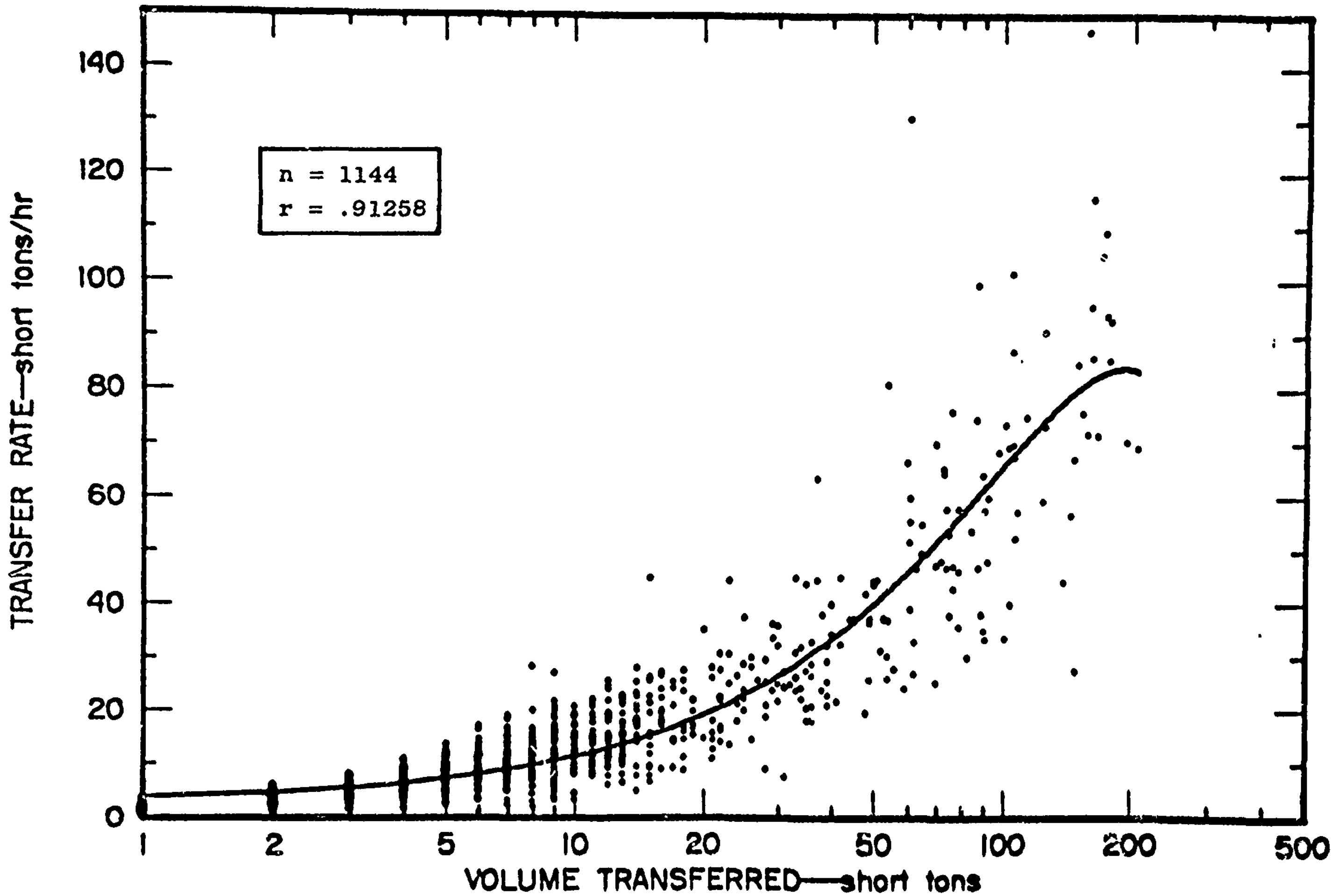


Figure A-34 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR DAYTIME PROVISIONS REPLENISHMENTS IN WESTPAC

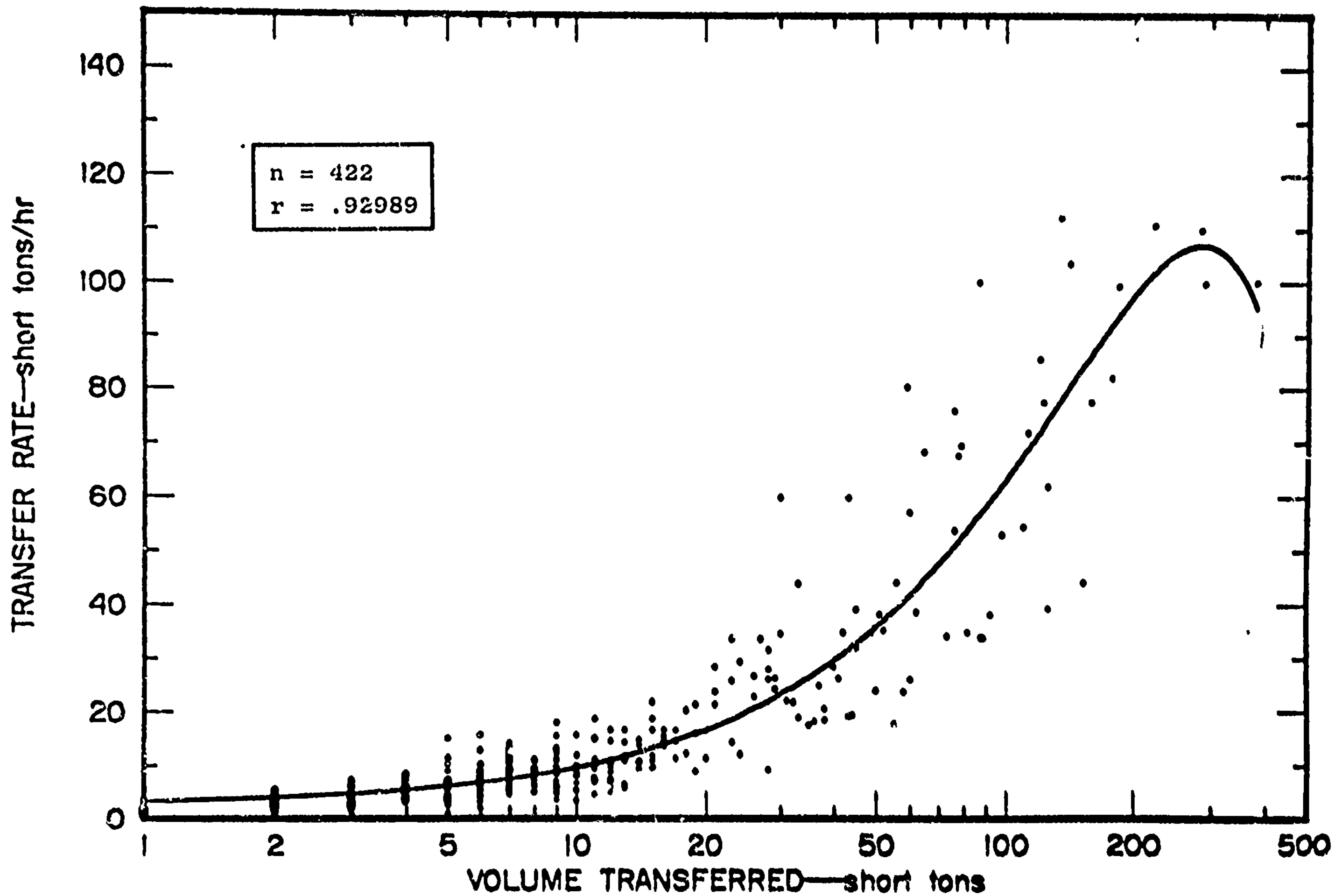


Figure A-35 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NIGHTTIME PROVISIONS REPLENISHMENTS IN WESTPAC

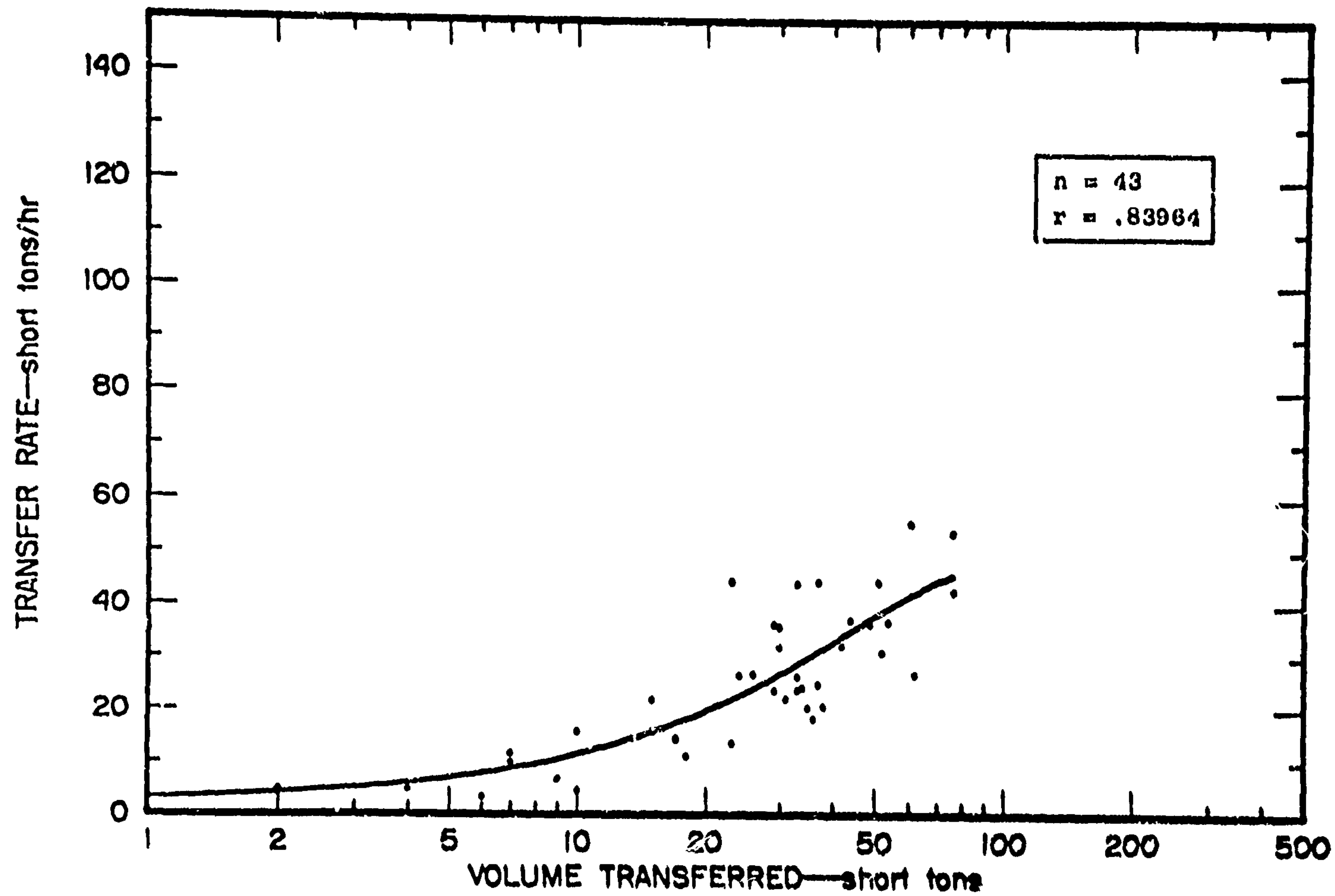


Figure A-36 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CA, CAG, AND CLG TYPES

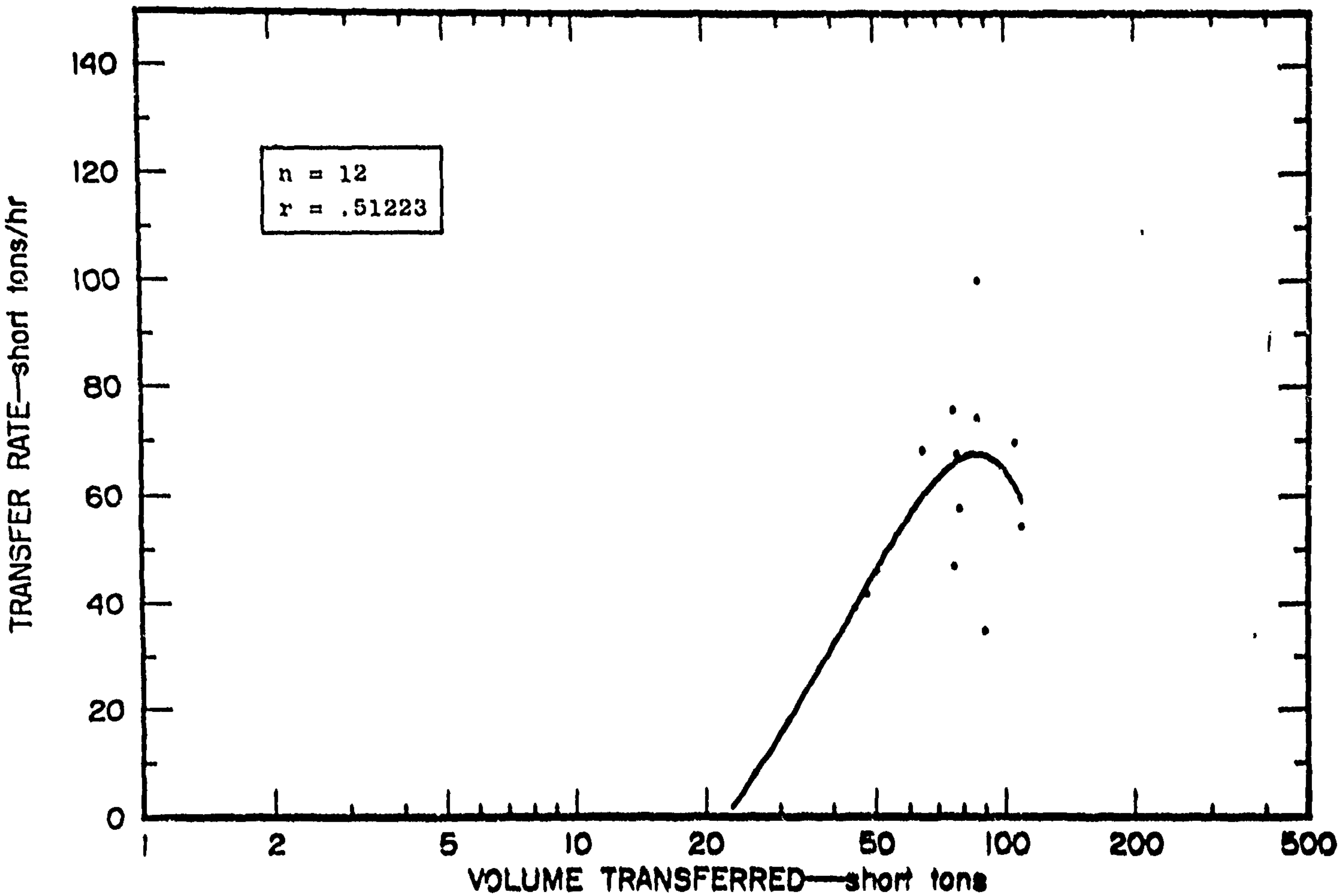


Figure A-37 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CVA 41-43

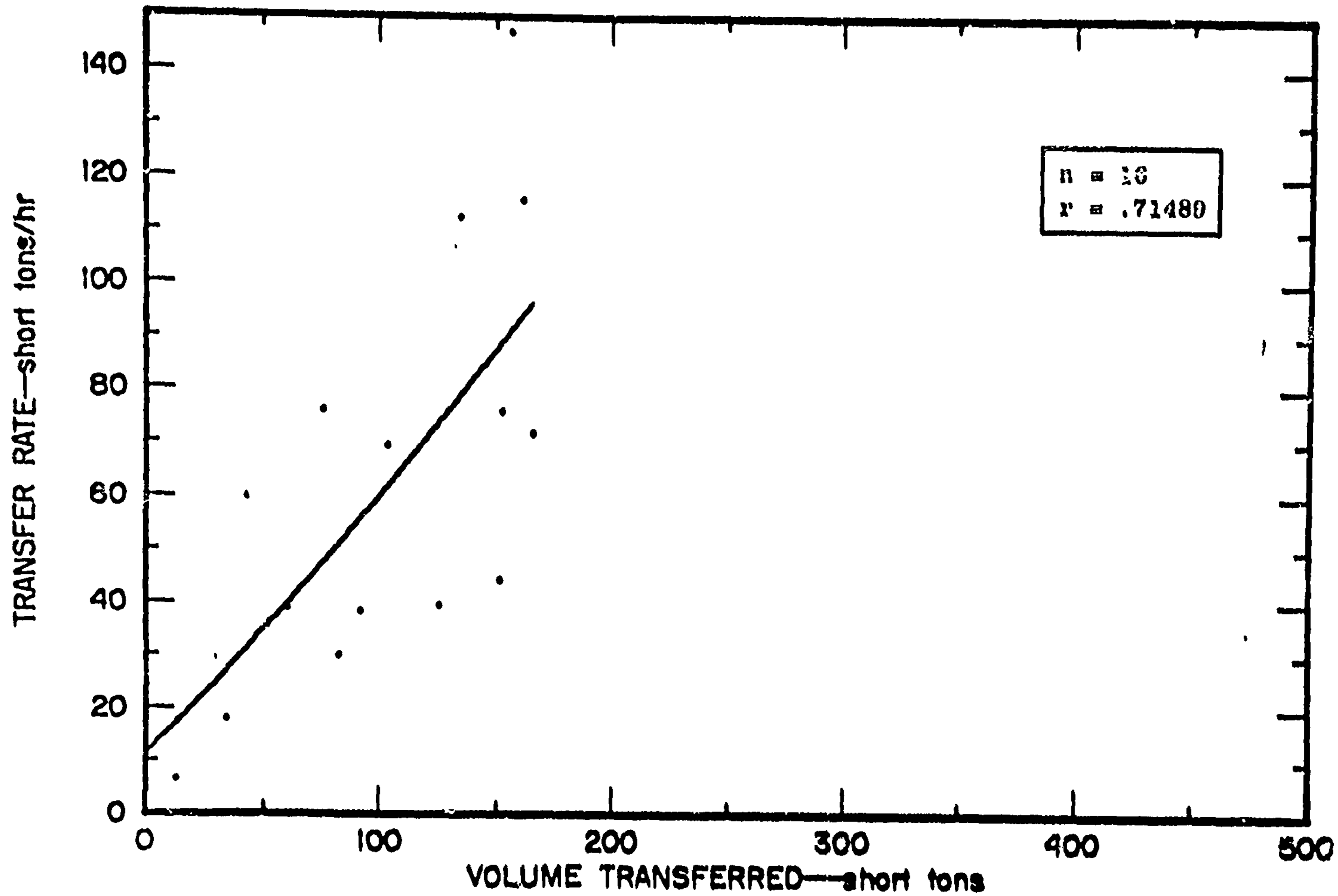


Figure A-38 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CVA 59-62

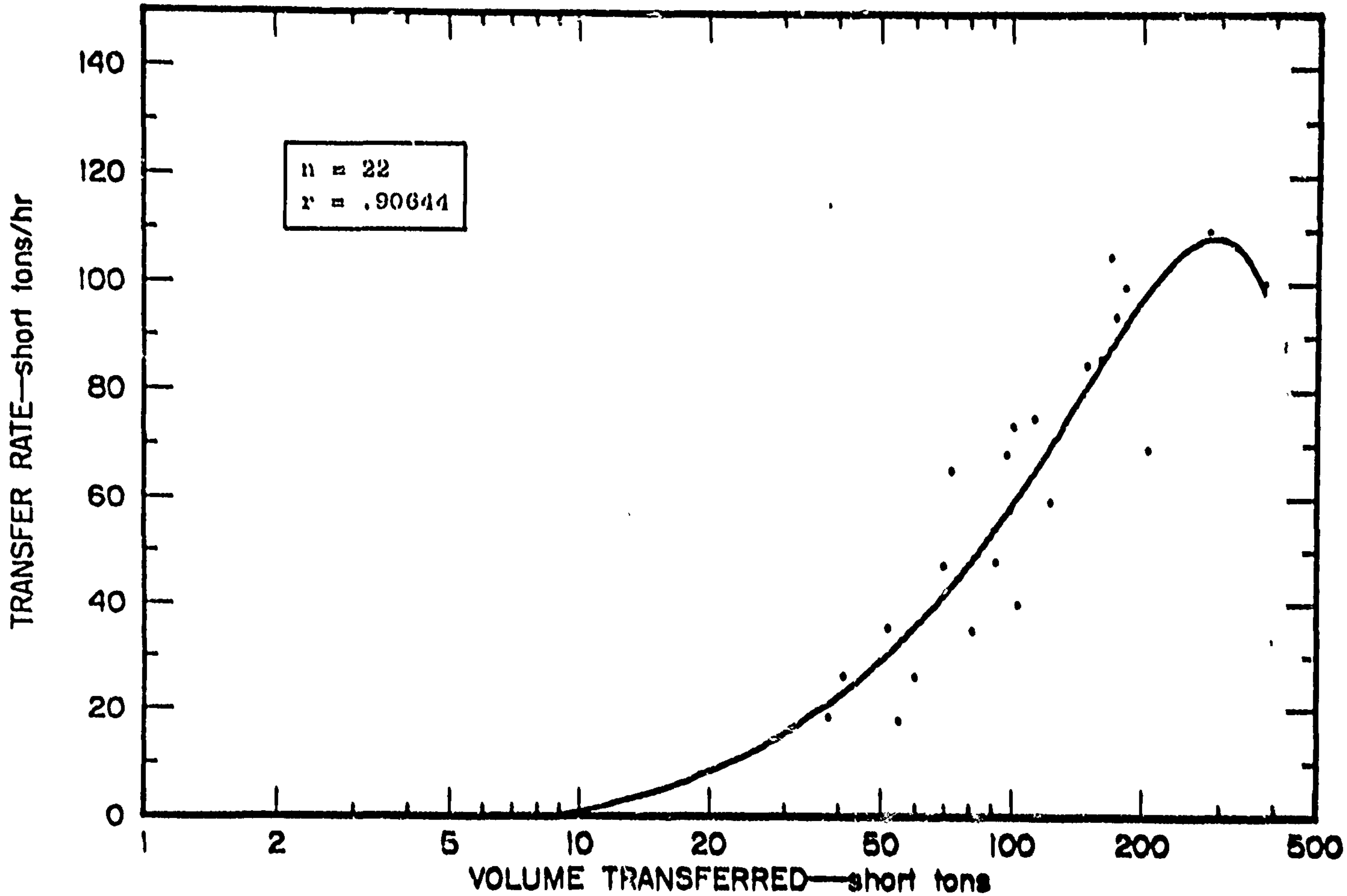


Figure A-39 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF CVA 63, 64 AND 66

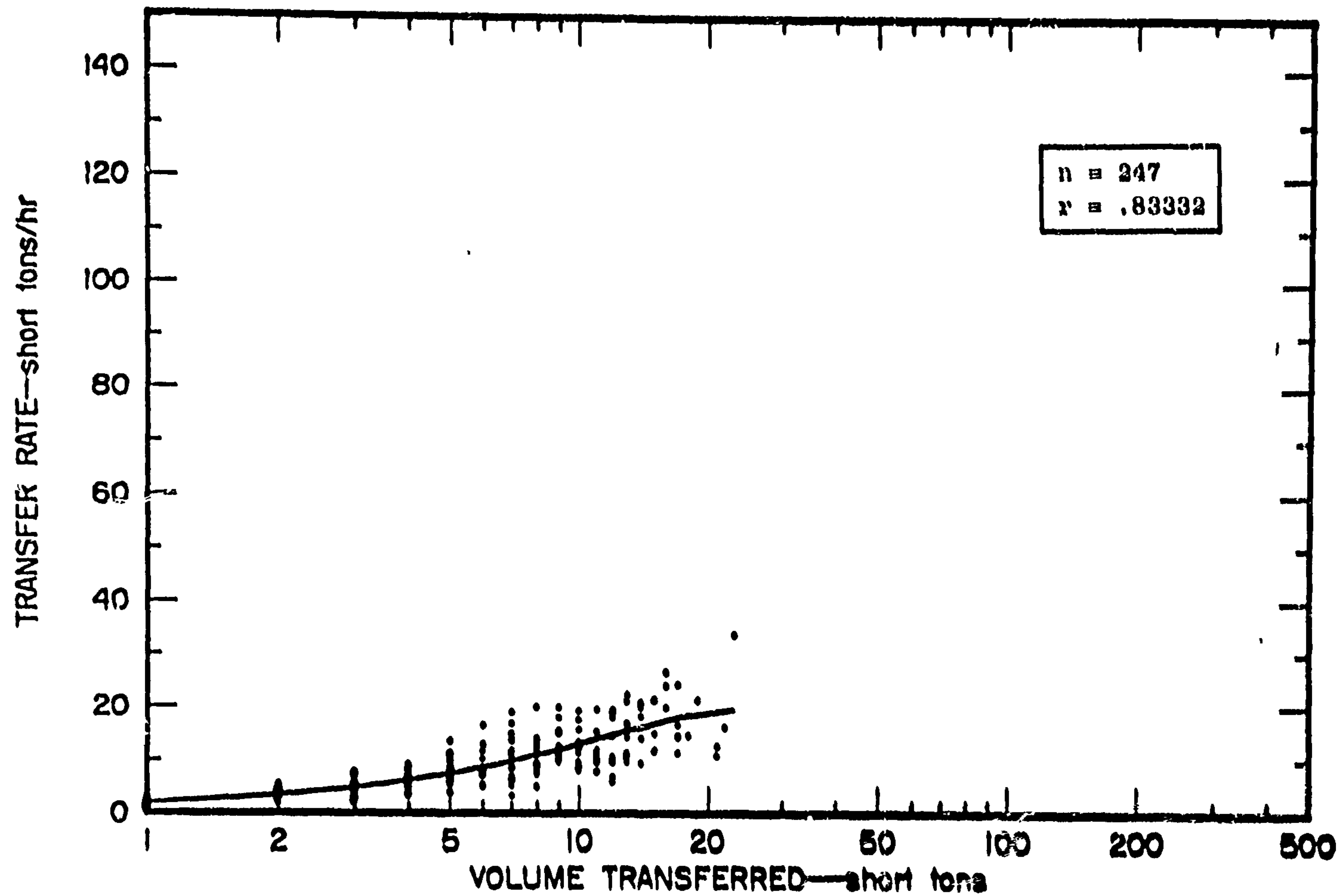


Figure A-40 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DD FRAM MK I CLASS

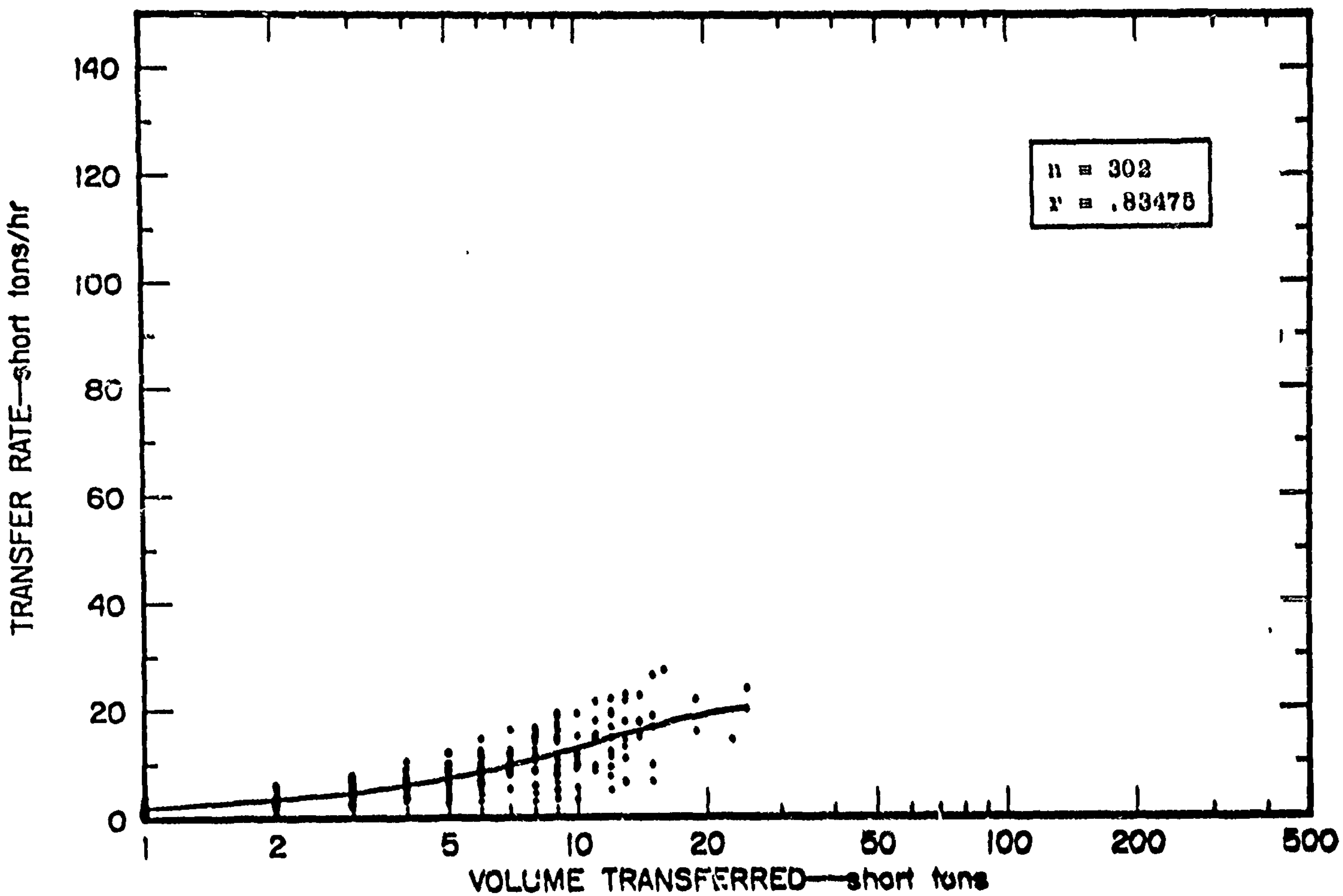


Figure A-41 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DD FRAM MK II CLASS

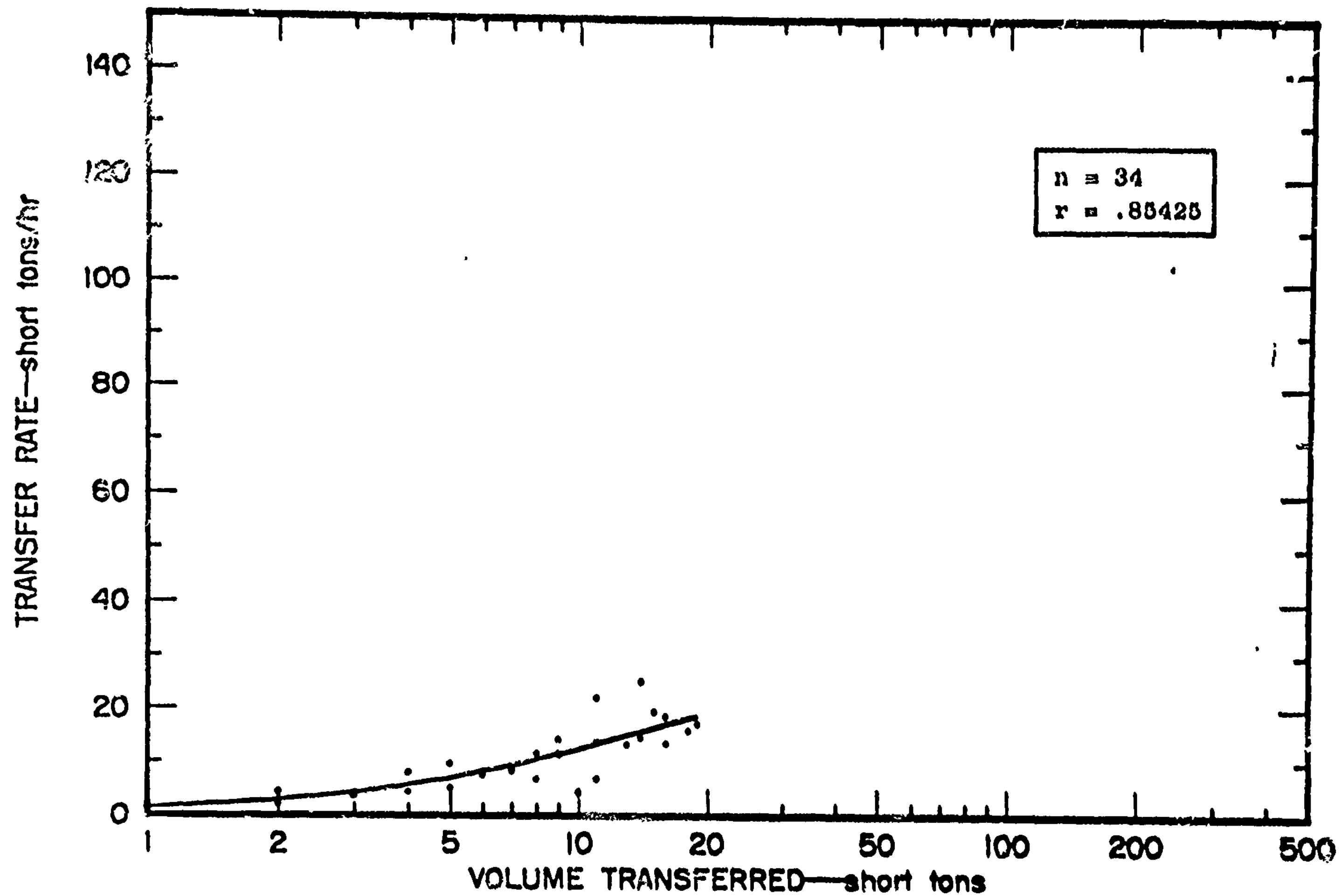


Figure A-42 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DD 931 AND 945 CLASSES

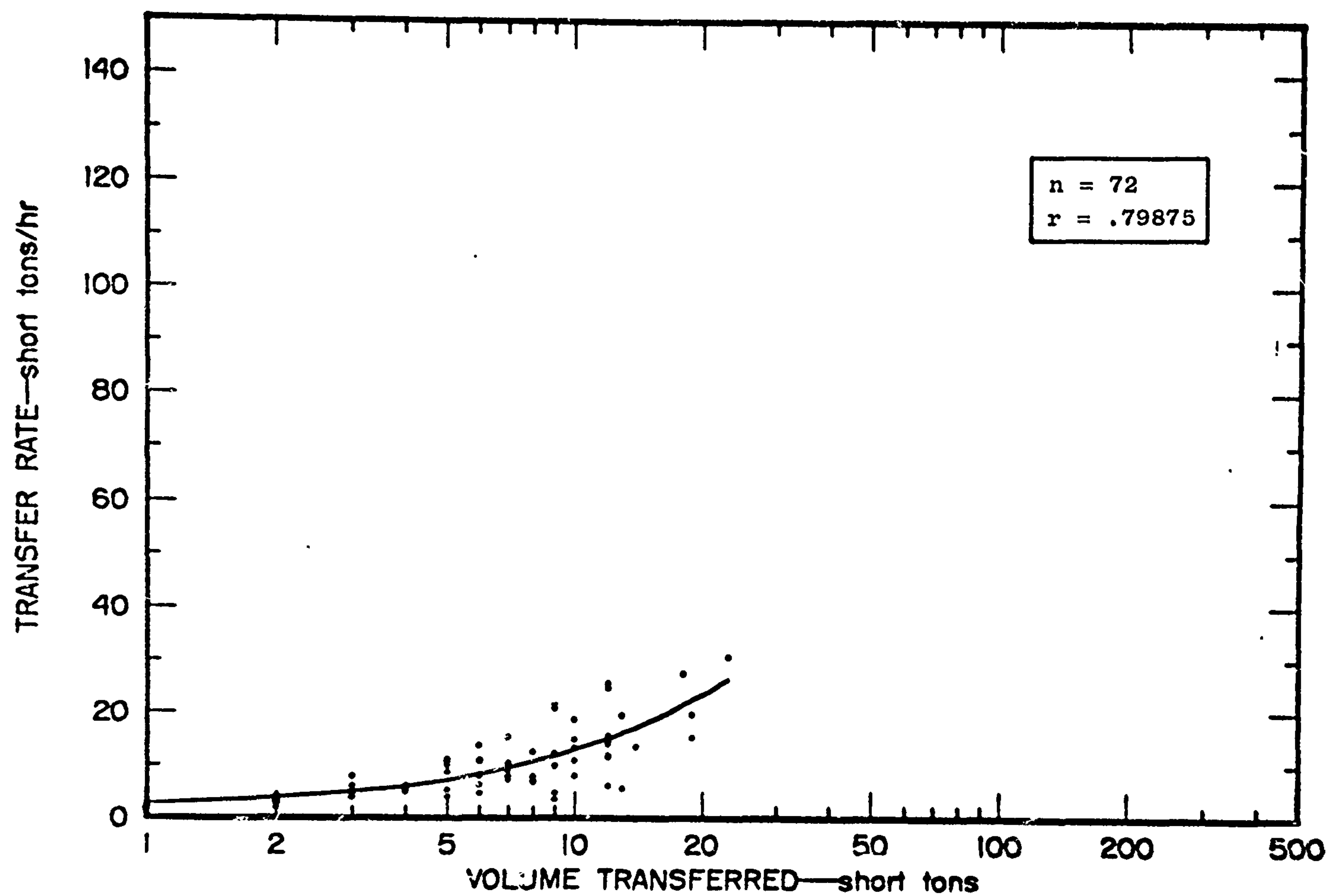


Figure A-43 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DDG TYPE

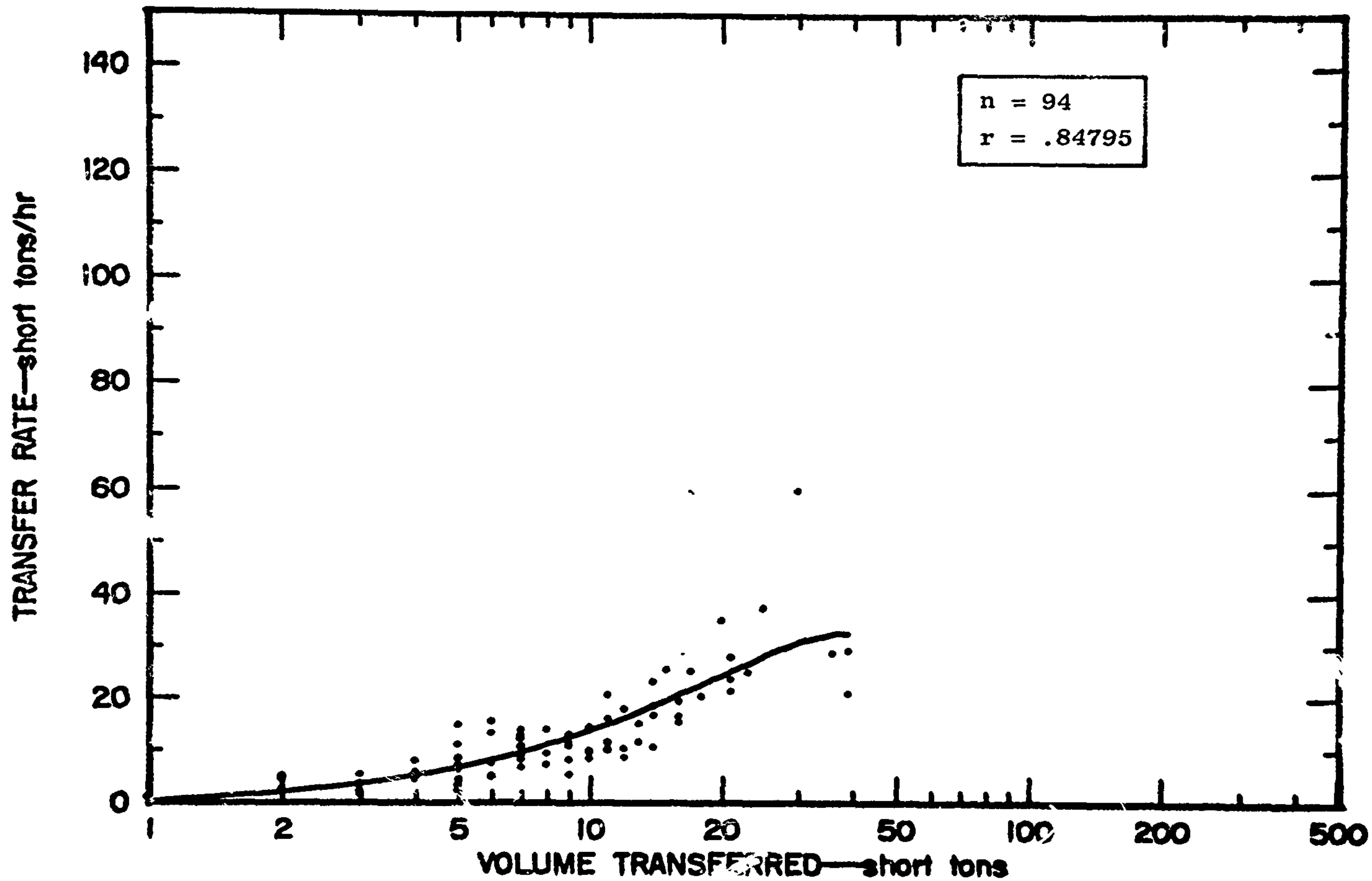


Figure A-44 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DL, DLG AND DLGN TYPES

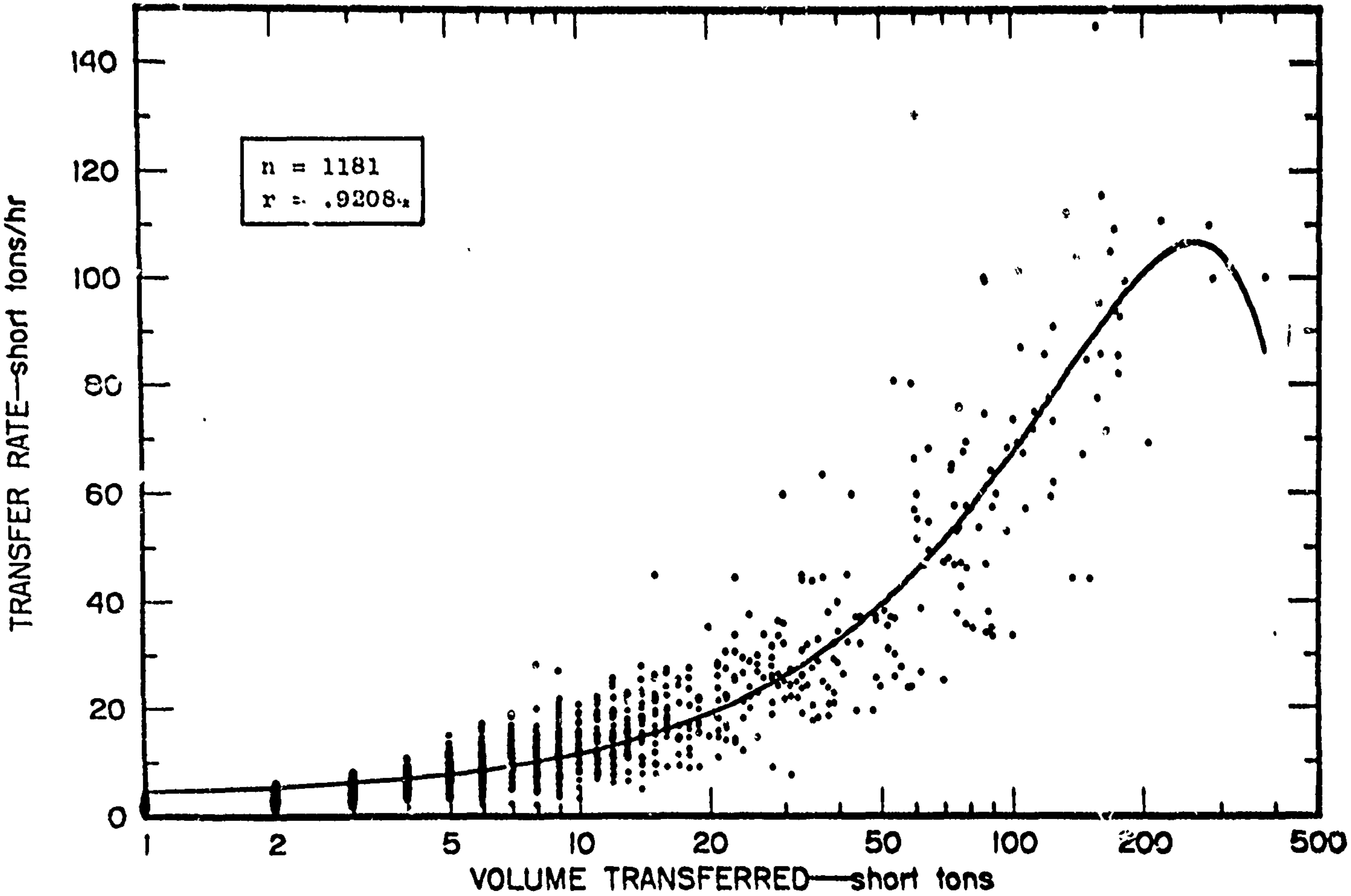


Figure A-45 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS BY AFS TYPE

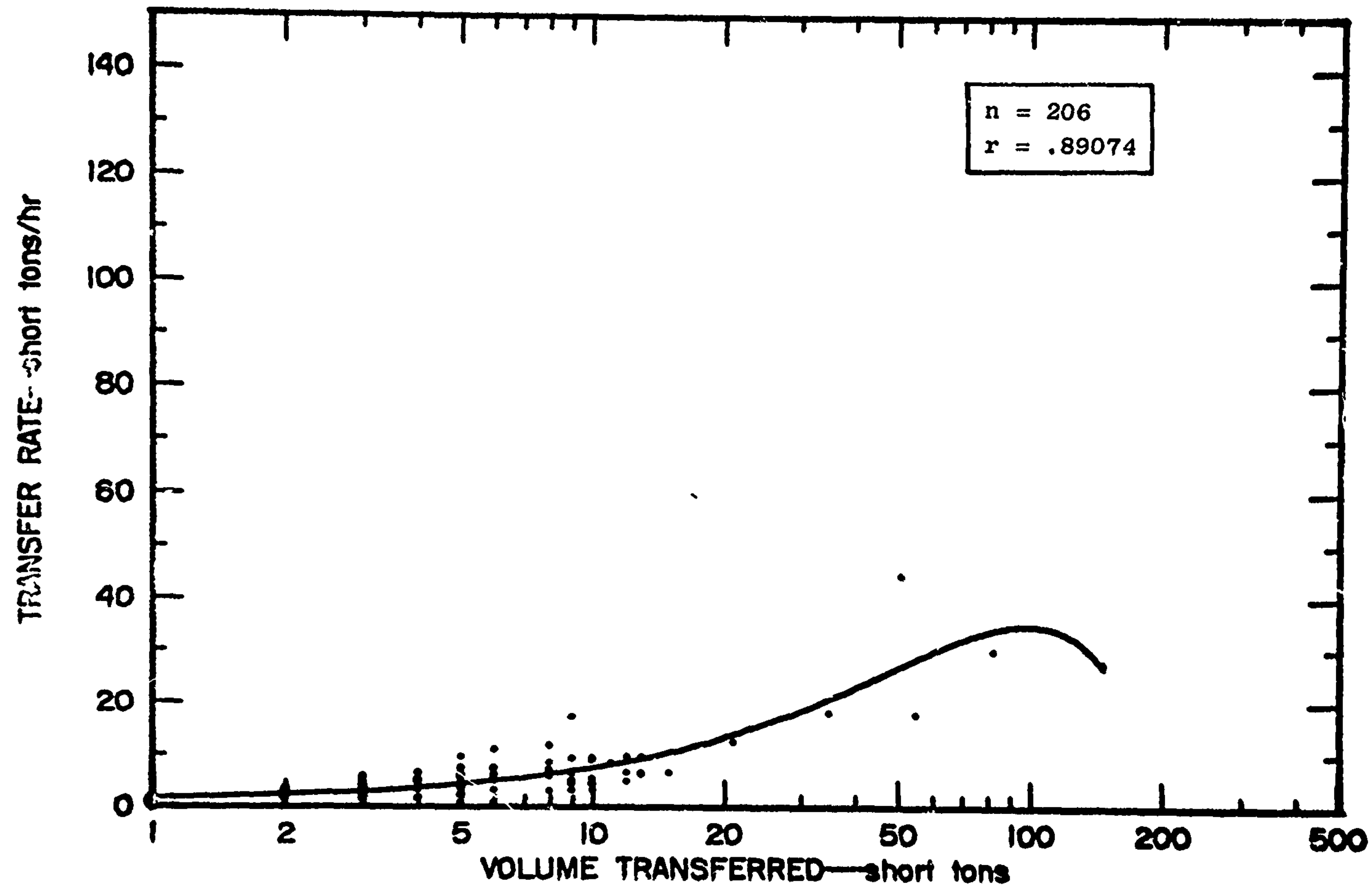


Figure A-46 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS BY AOE TYPE

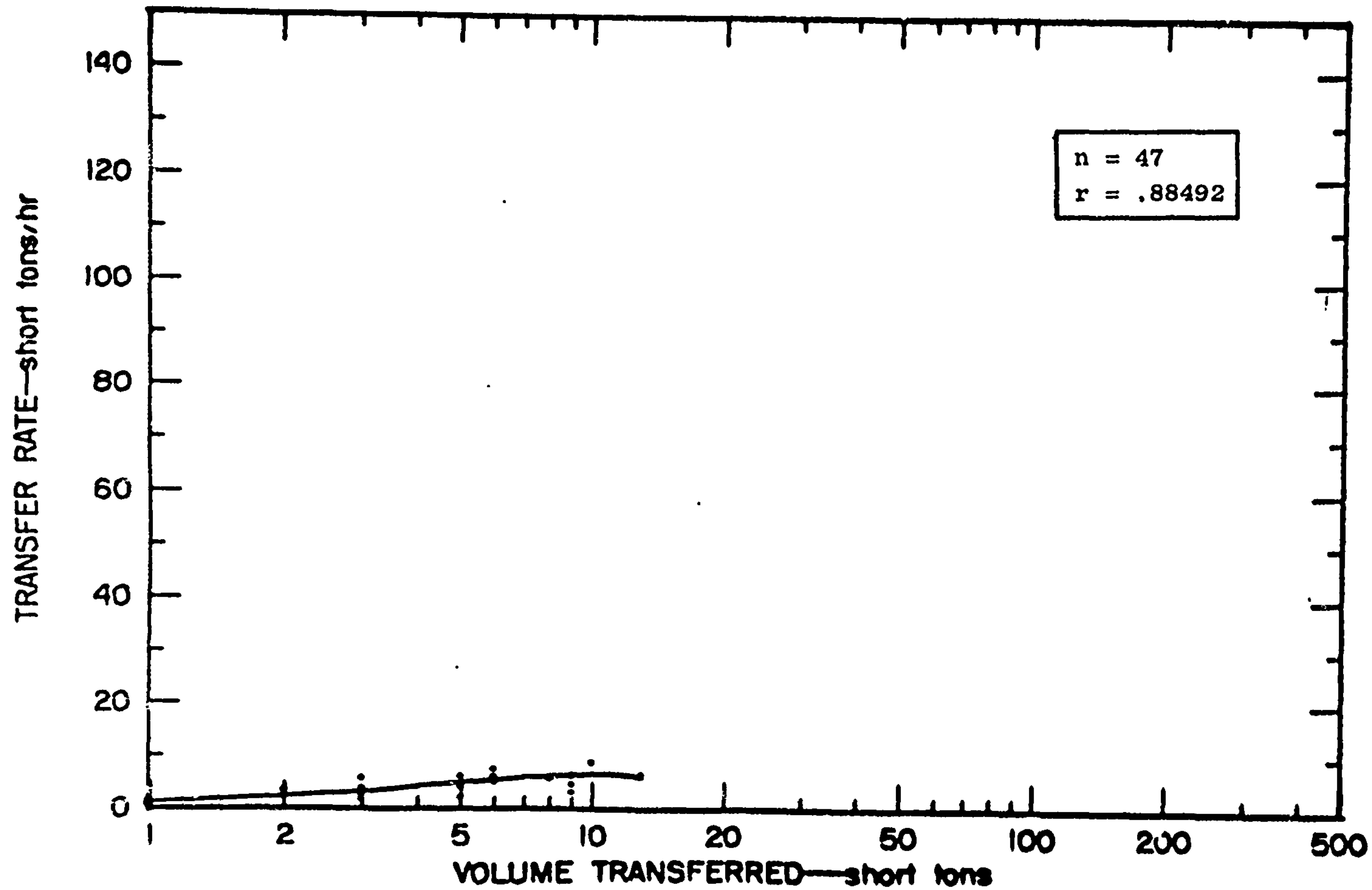


Figure A-47 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DD CLASSES OTHER THAN FRAM MK I, FRAM MK II, 931 AND 945 BY AOE TYPE

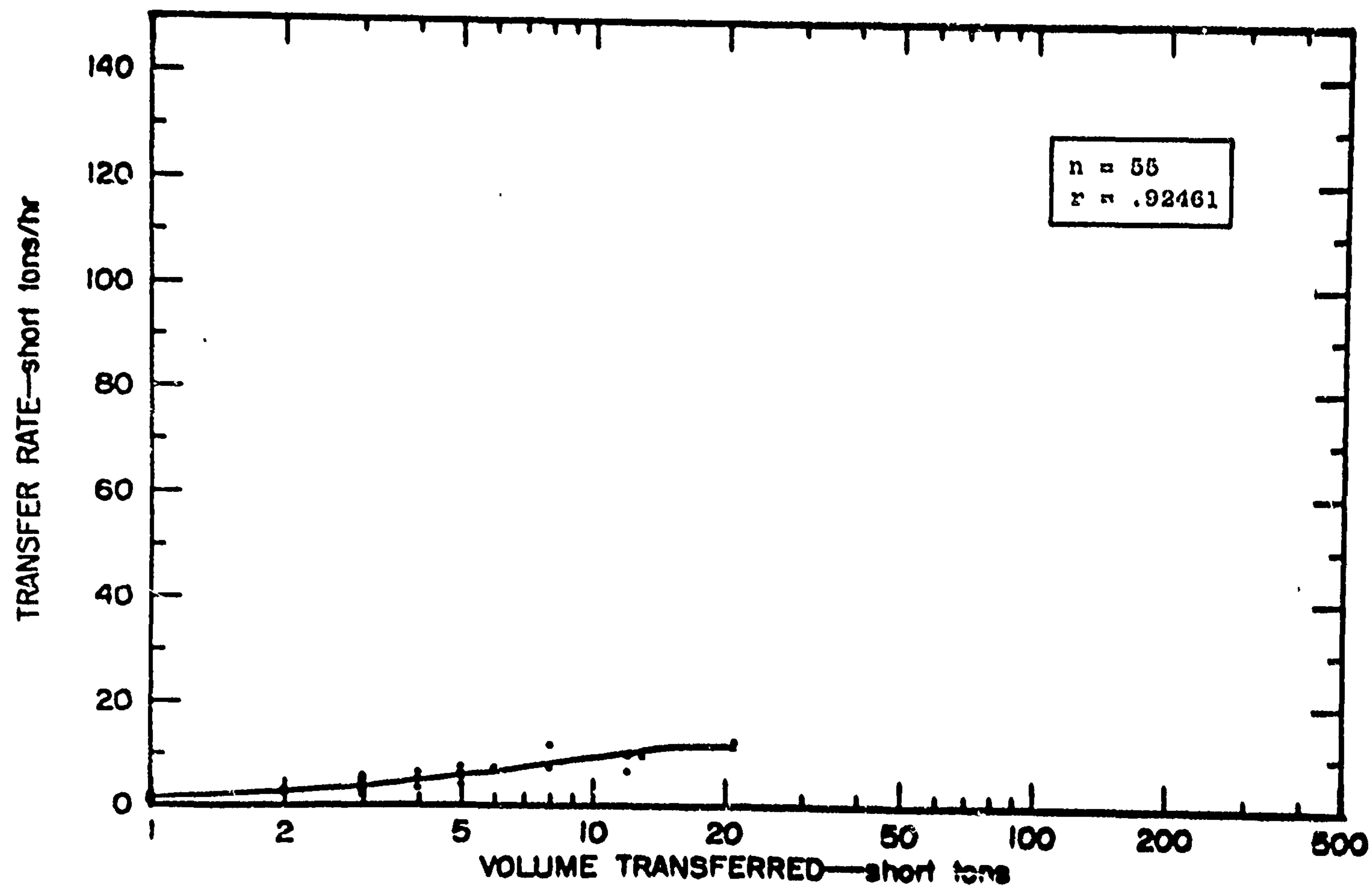


Figure A-48 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DD FRAM MK I CLASS BY AOE TYPE

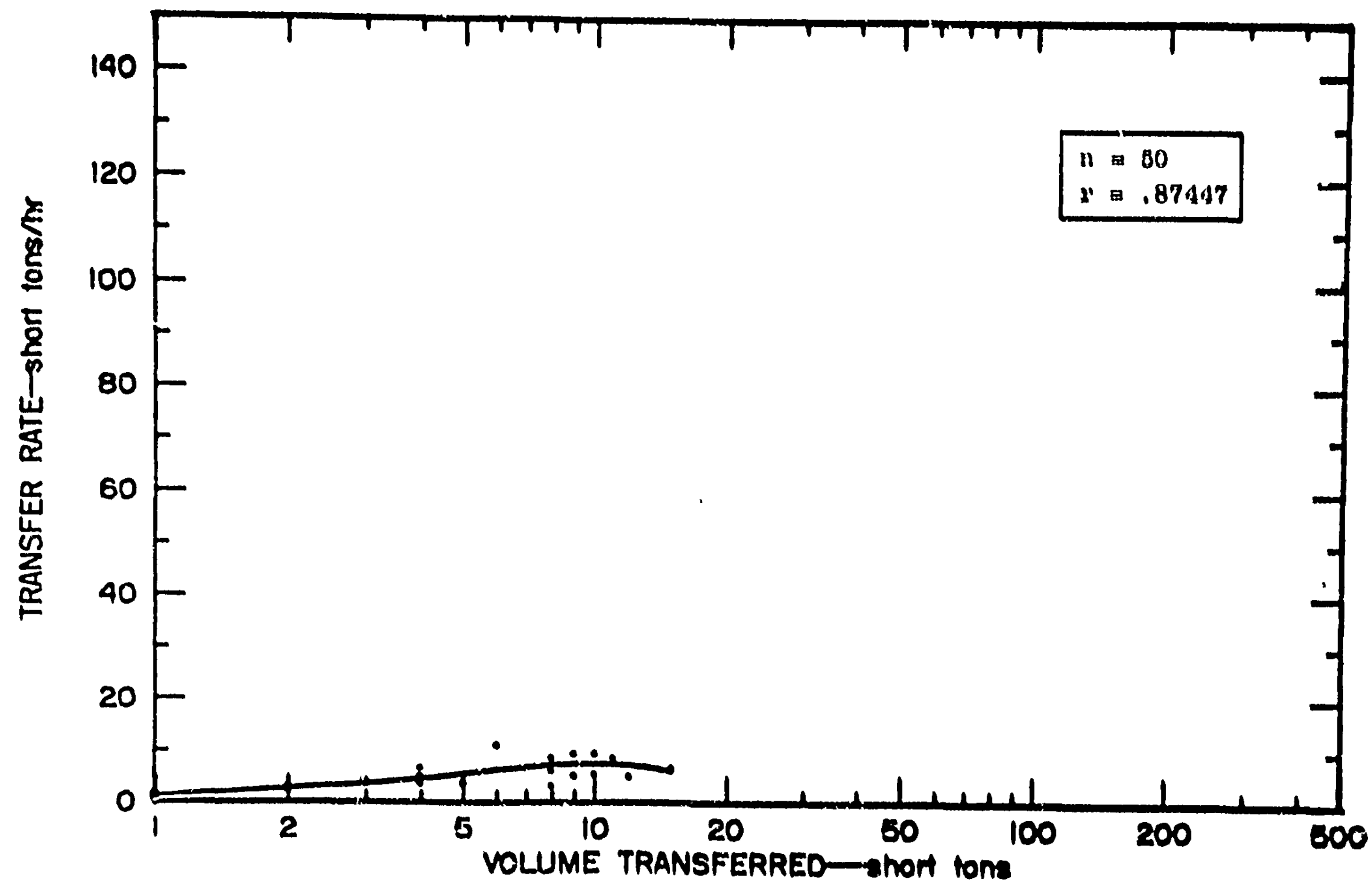


Figure A-49 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DD FRAM MK II CLASS BY AOE TYPE

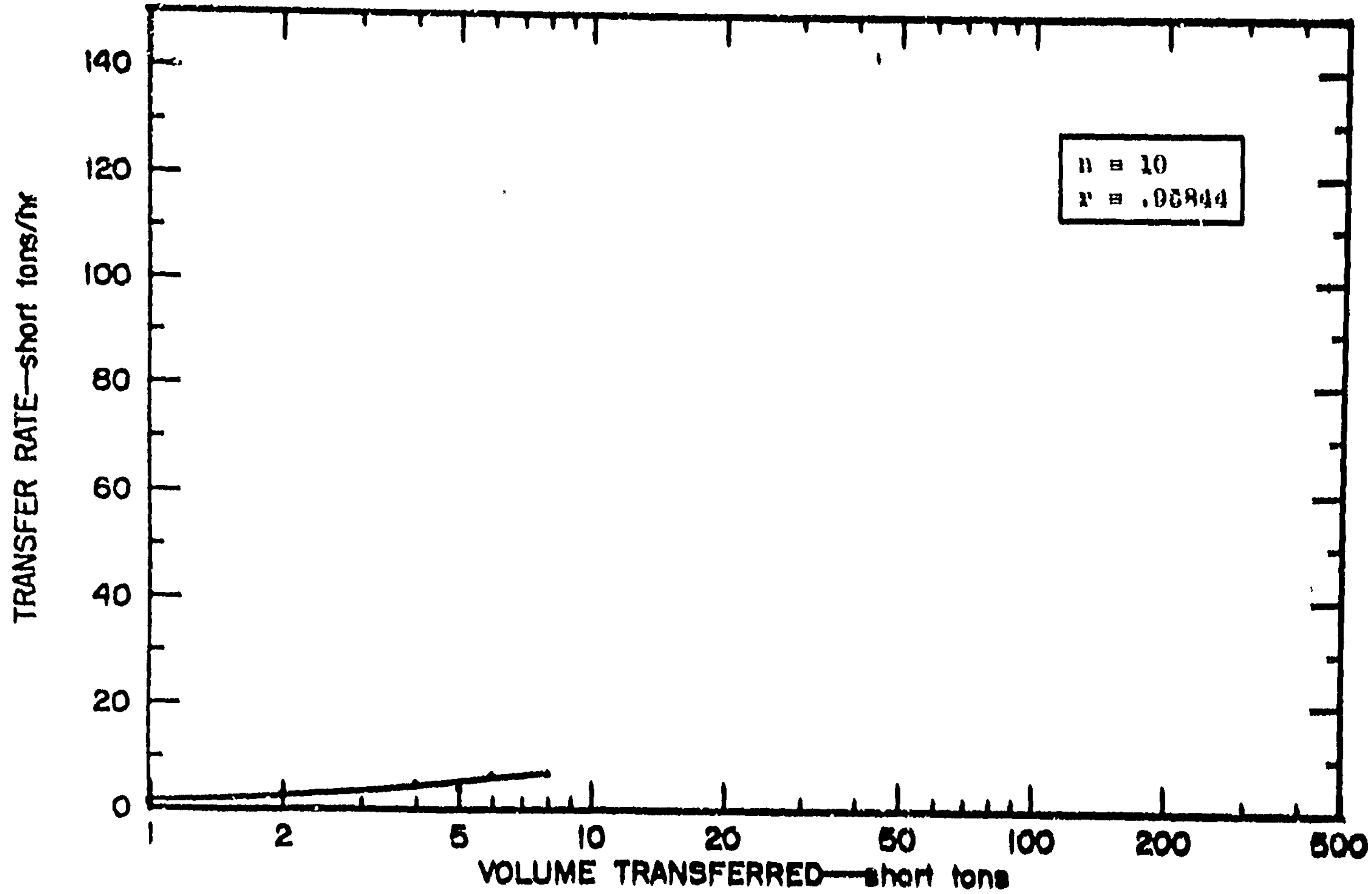


Figure A-50 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DDG TYPE BY AOE TYPE

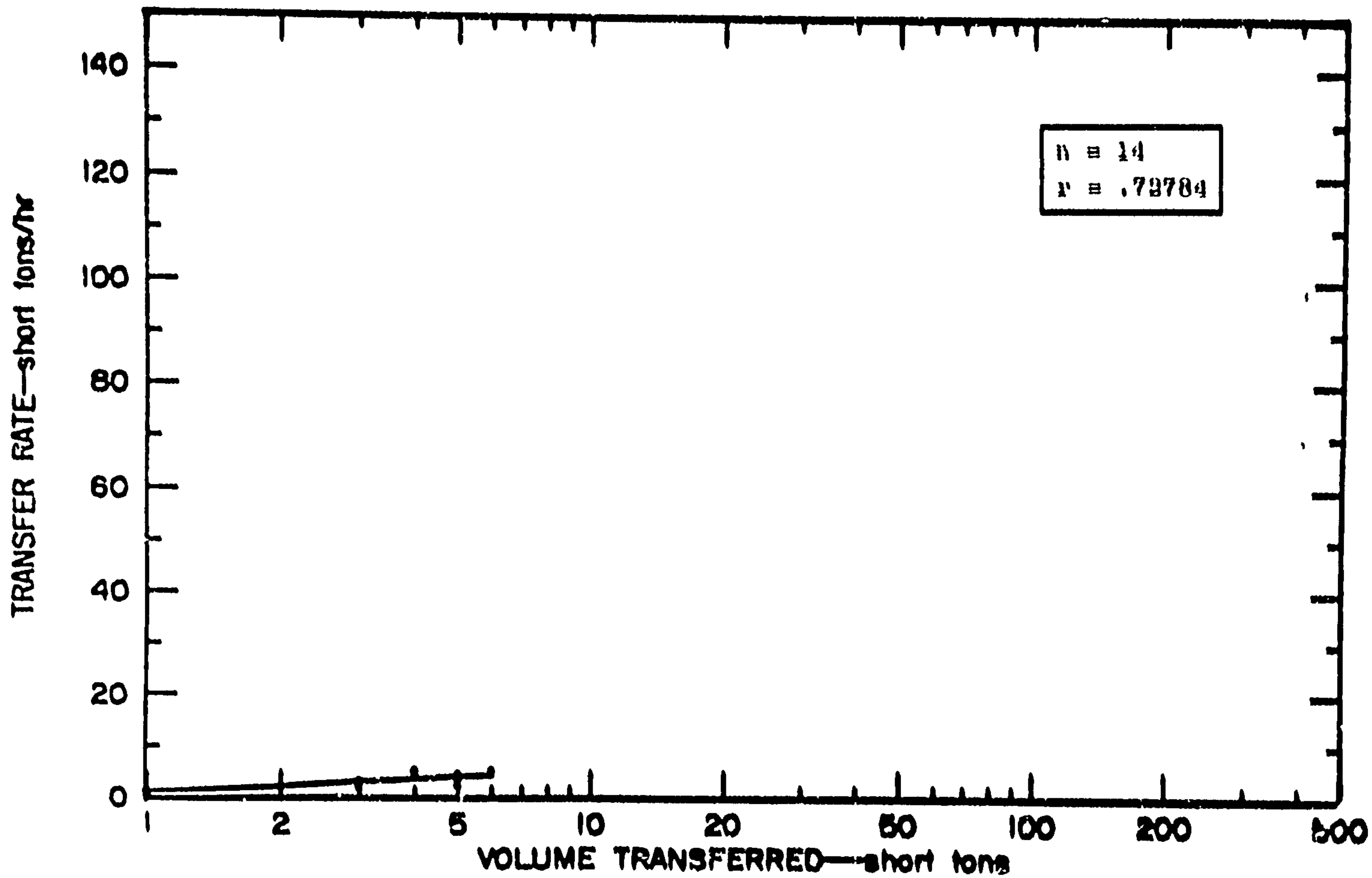


Figure A-51 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR PROVISIONS REPLENISHMENTS OF DL, DLG, AND DLGN TYPES BY AOE TYPE

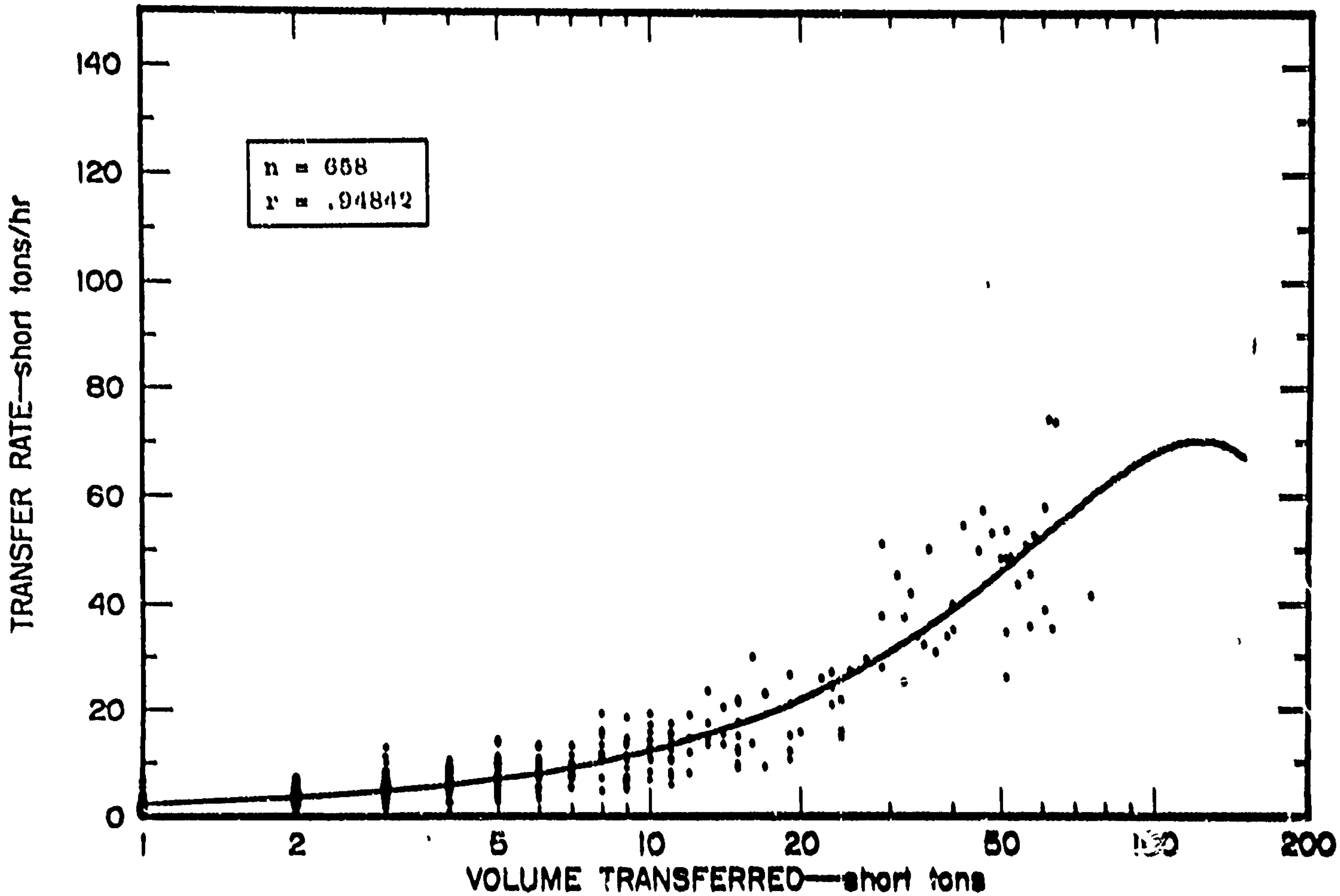


Figure A-52 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR ALL STORES PROVISIONS

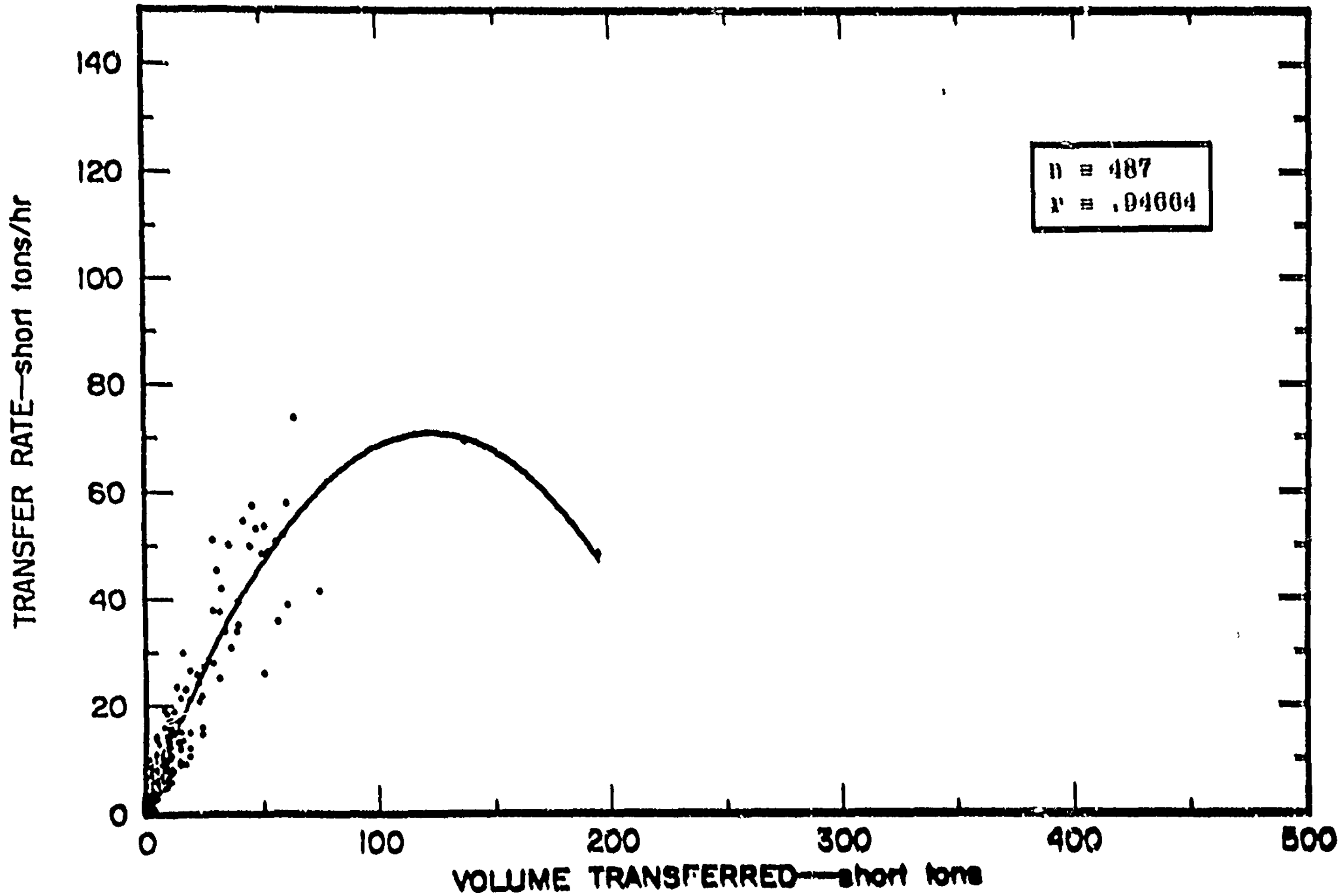


Figure A-53 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR DAYTIME STORES REPLENISHMENTS

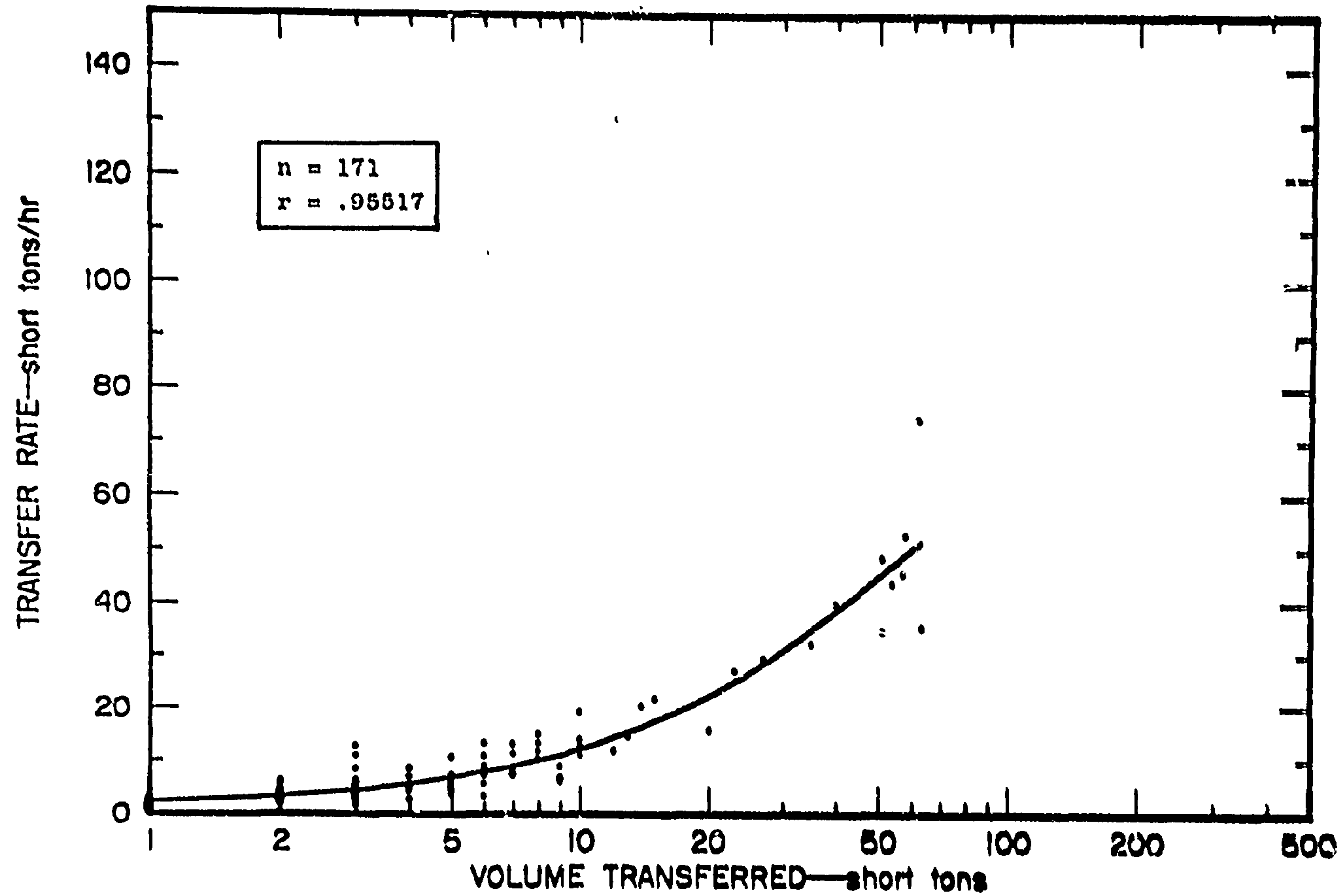
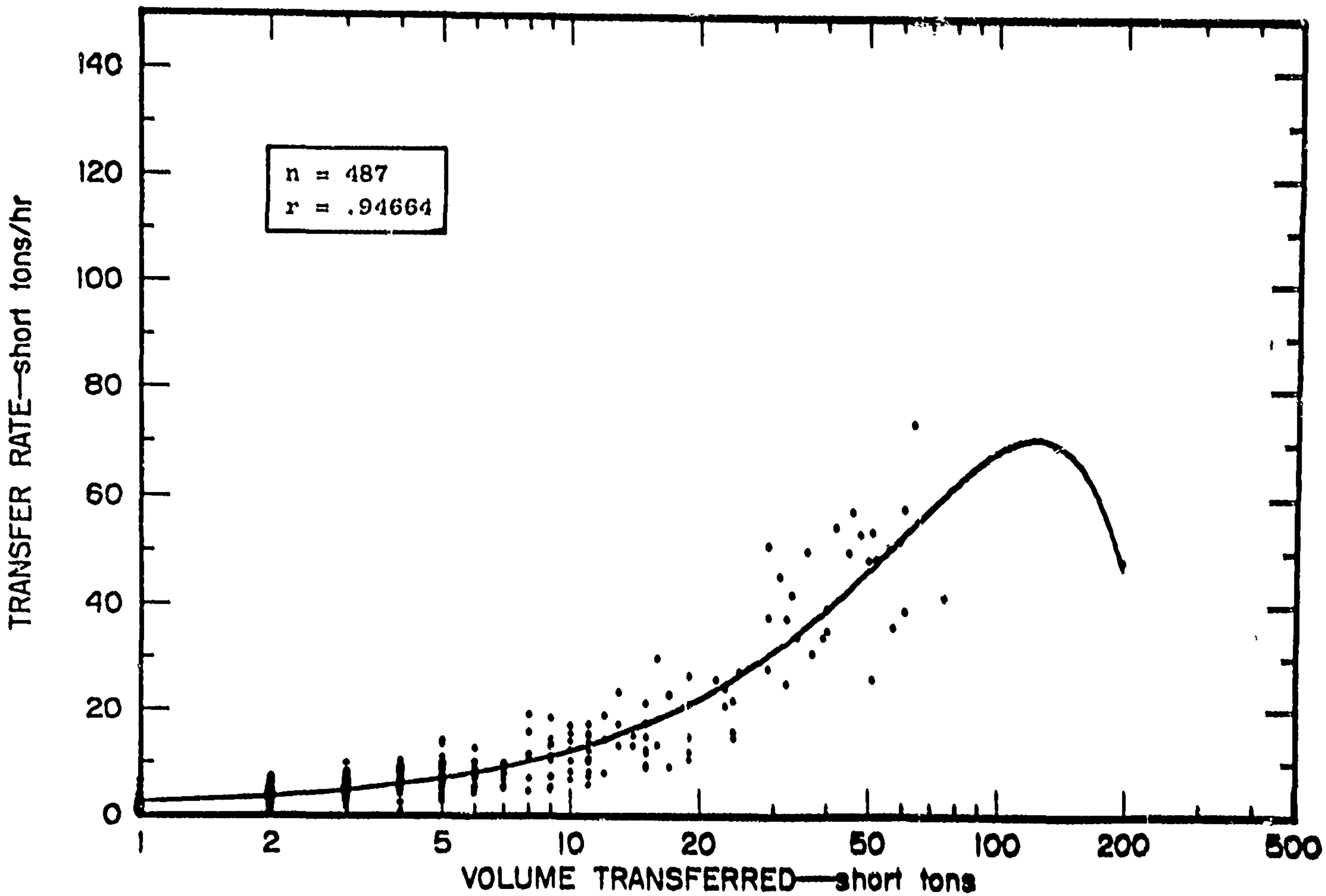


Figure A-54 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NIGHTTIME STORES REPLENISHMENTS



Figuro A-55 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR DAYTIME STORES REPLENISIMENTS IN WESTPAC

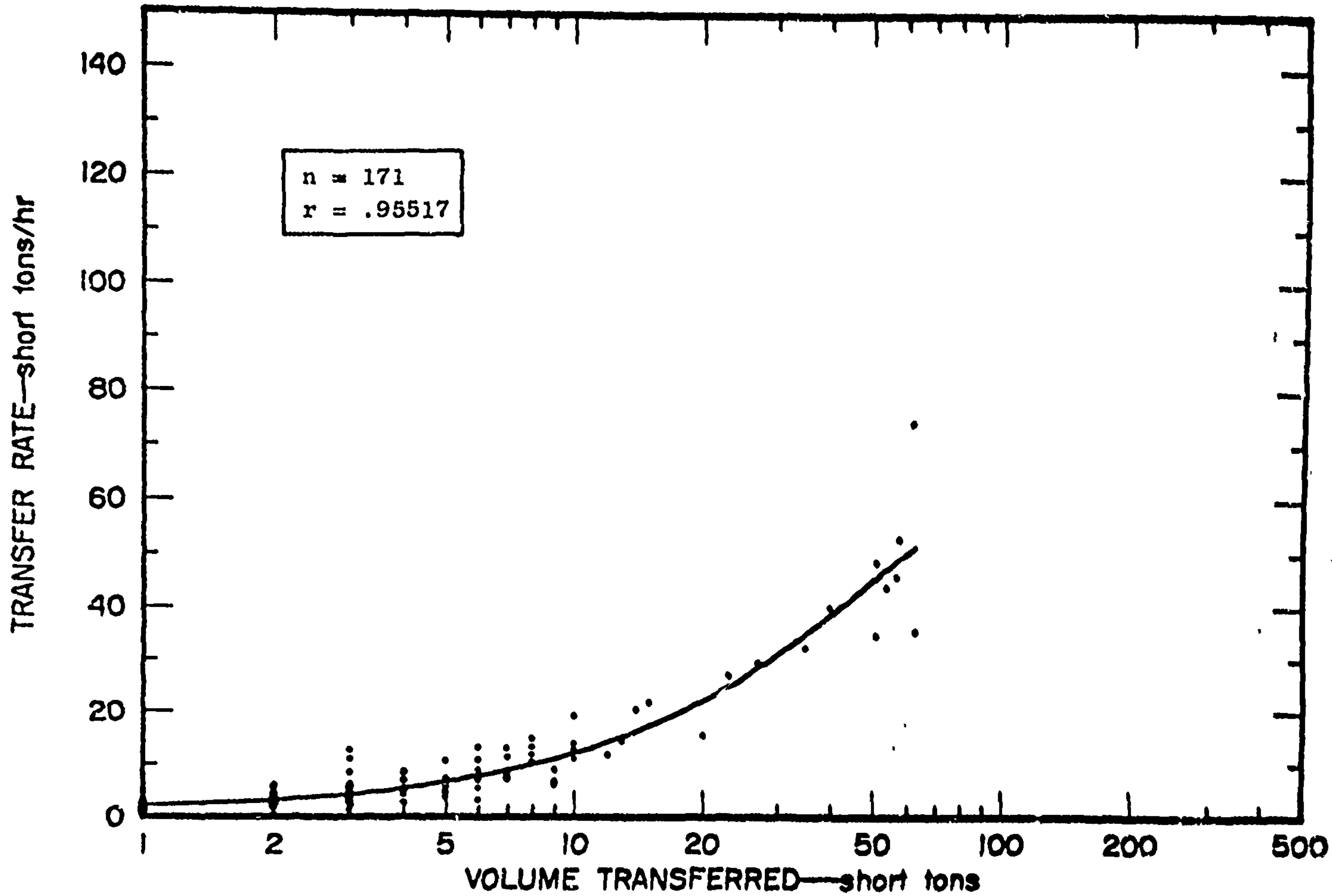


Figure A-56 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NIGHTTIME STORES REPLENISHMENTS IN WESTPAC

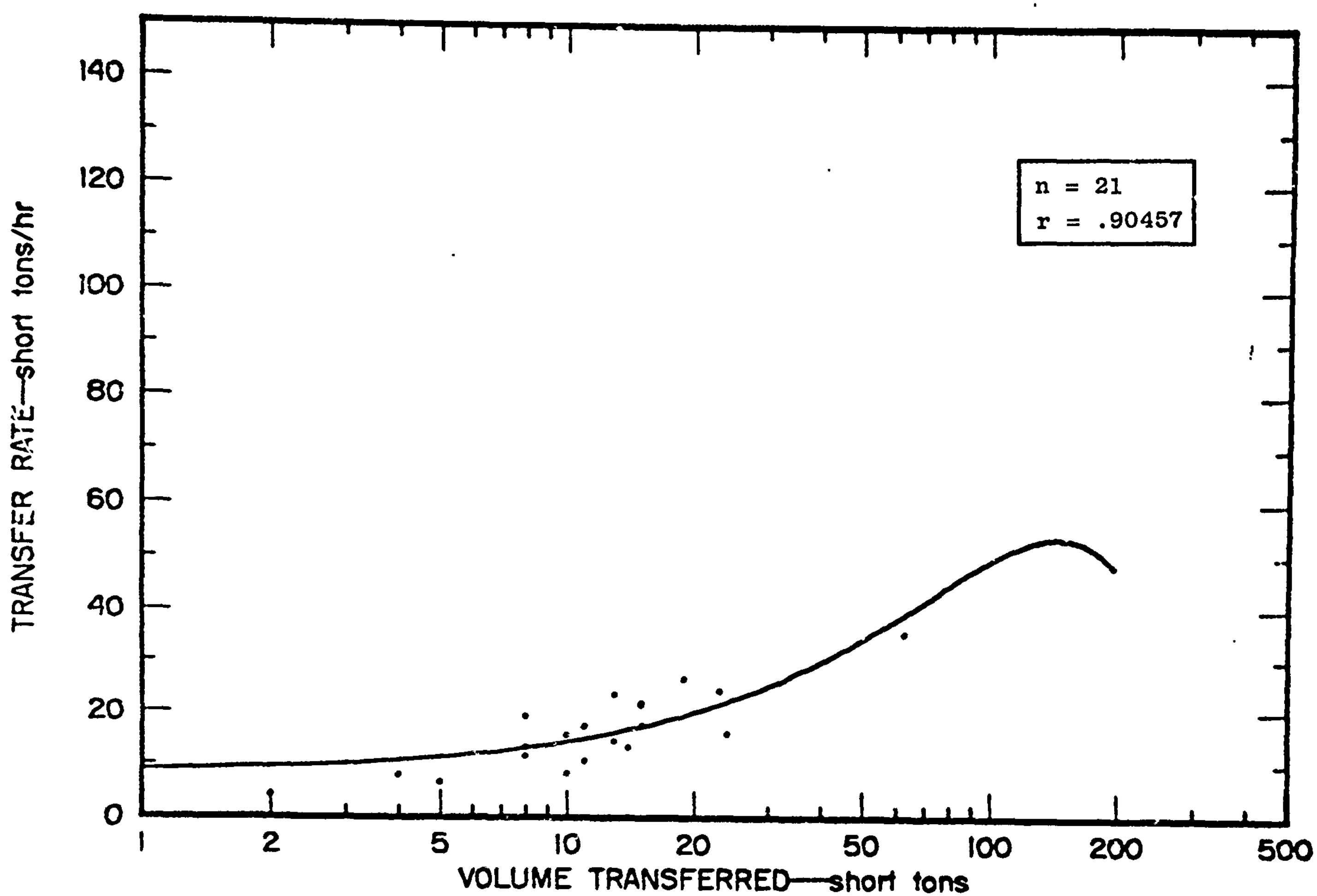


Figure A-57 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF CA, CAG, AND CLG TYPES

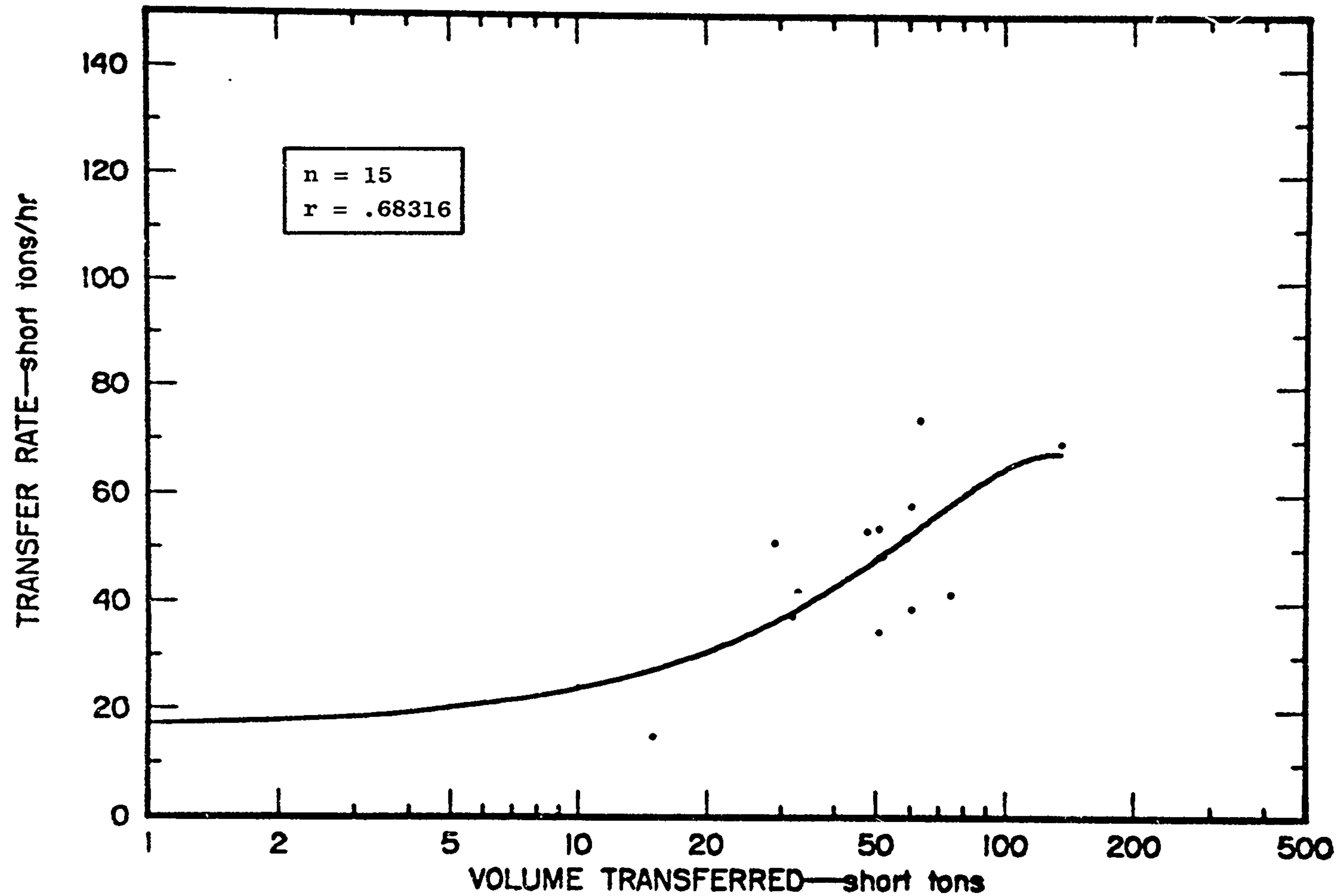


Figure A-58 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS FOR CVA 63, 64 AND 66

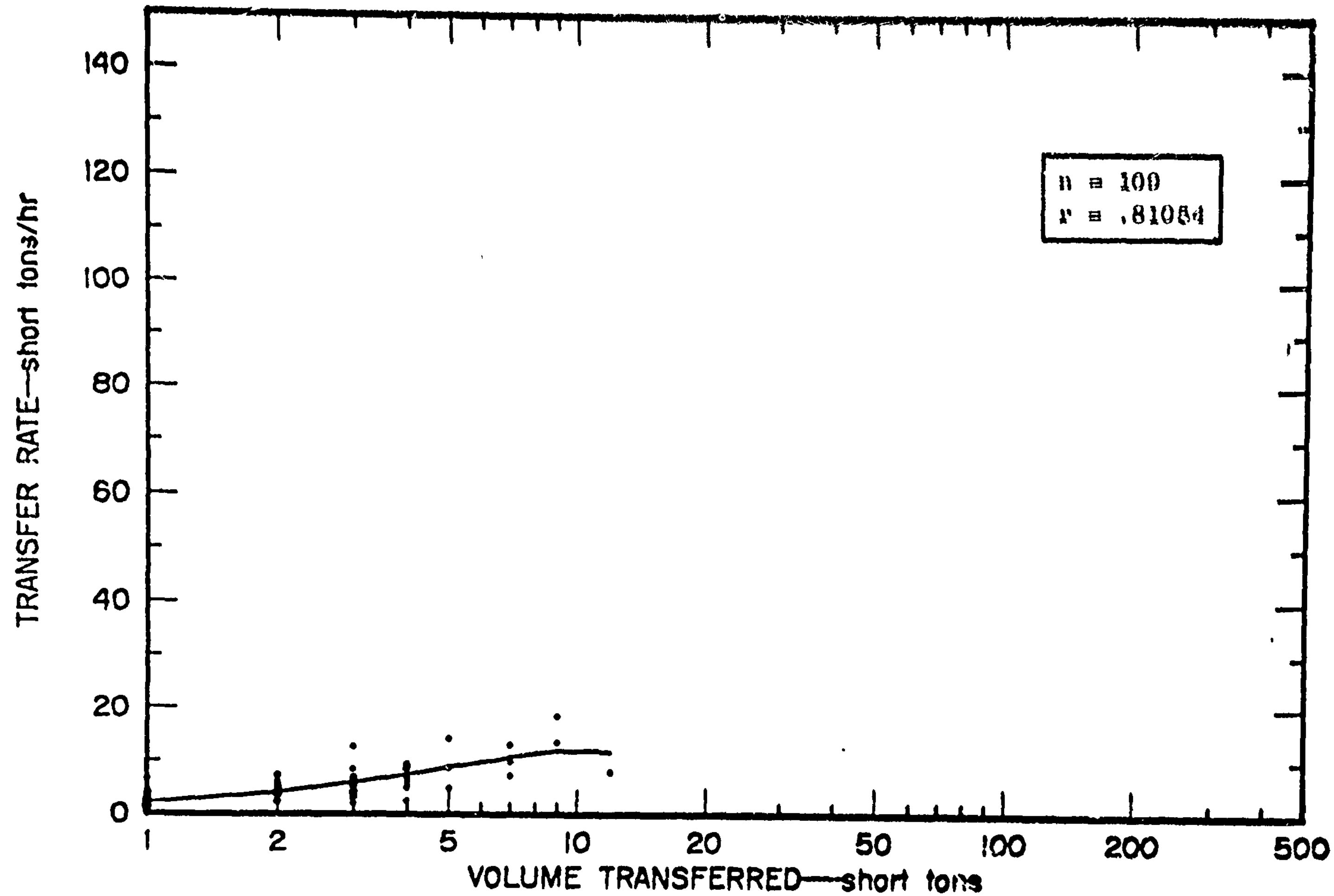


Figure A-59 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF DD FRAM MK I CLASS

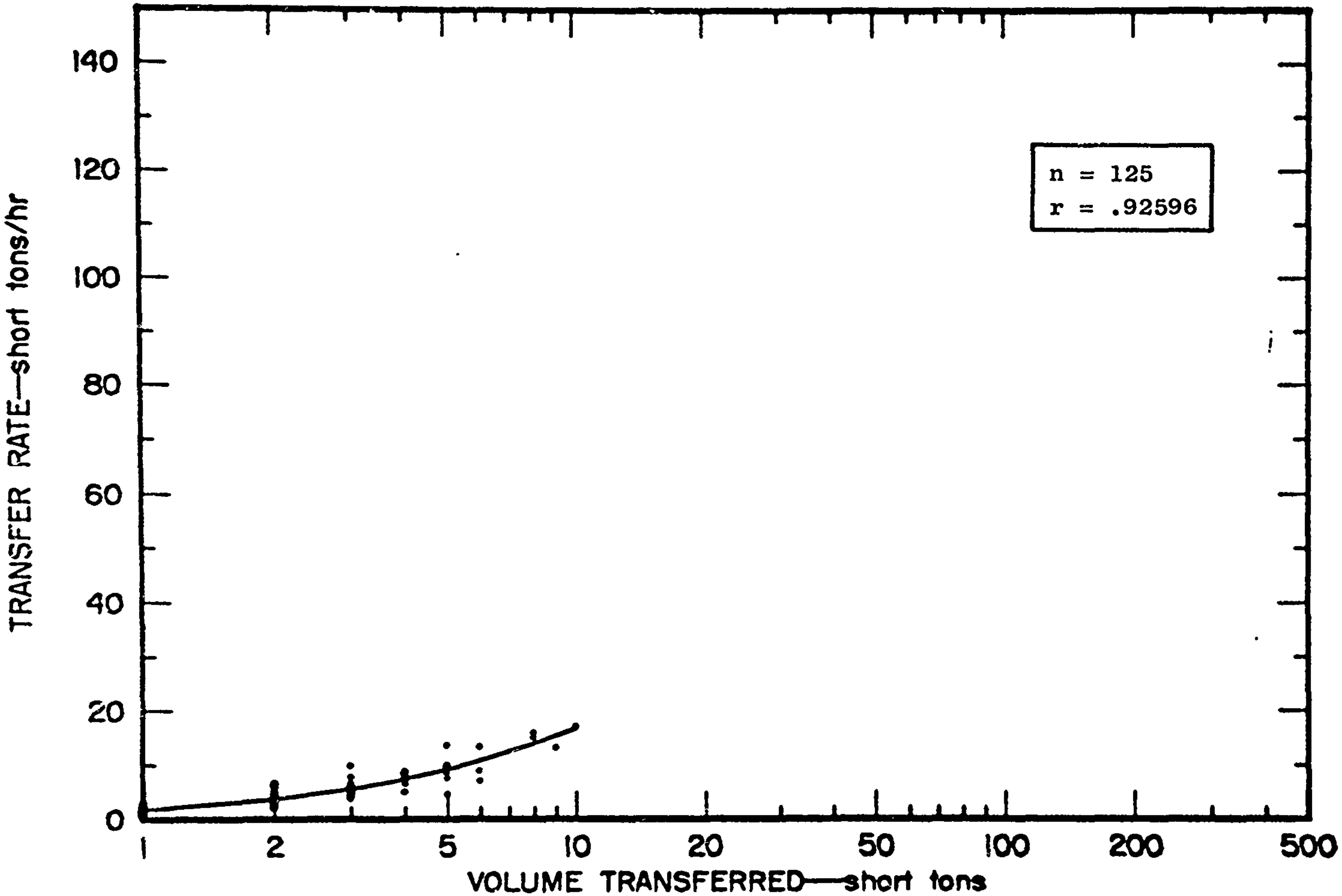


Figure A-60 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF DD FRAM MK II CLASS

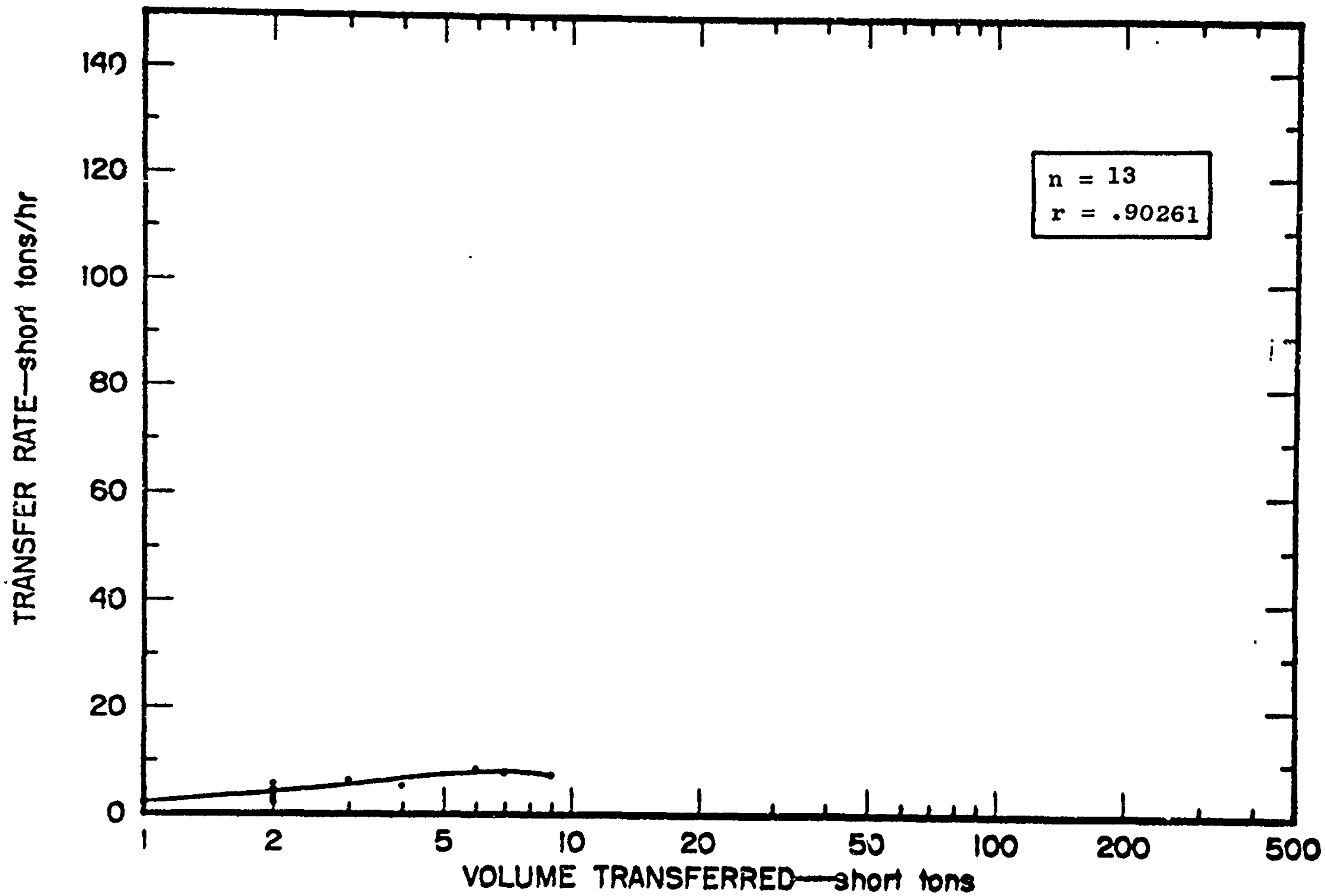


Figure A-61 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF DD 931 AND 945 CLASSES

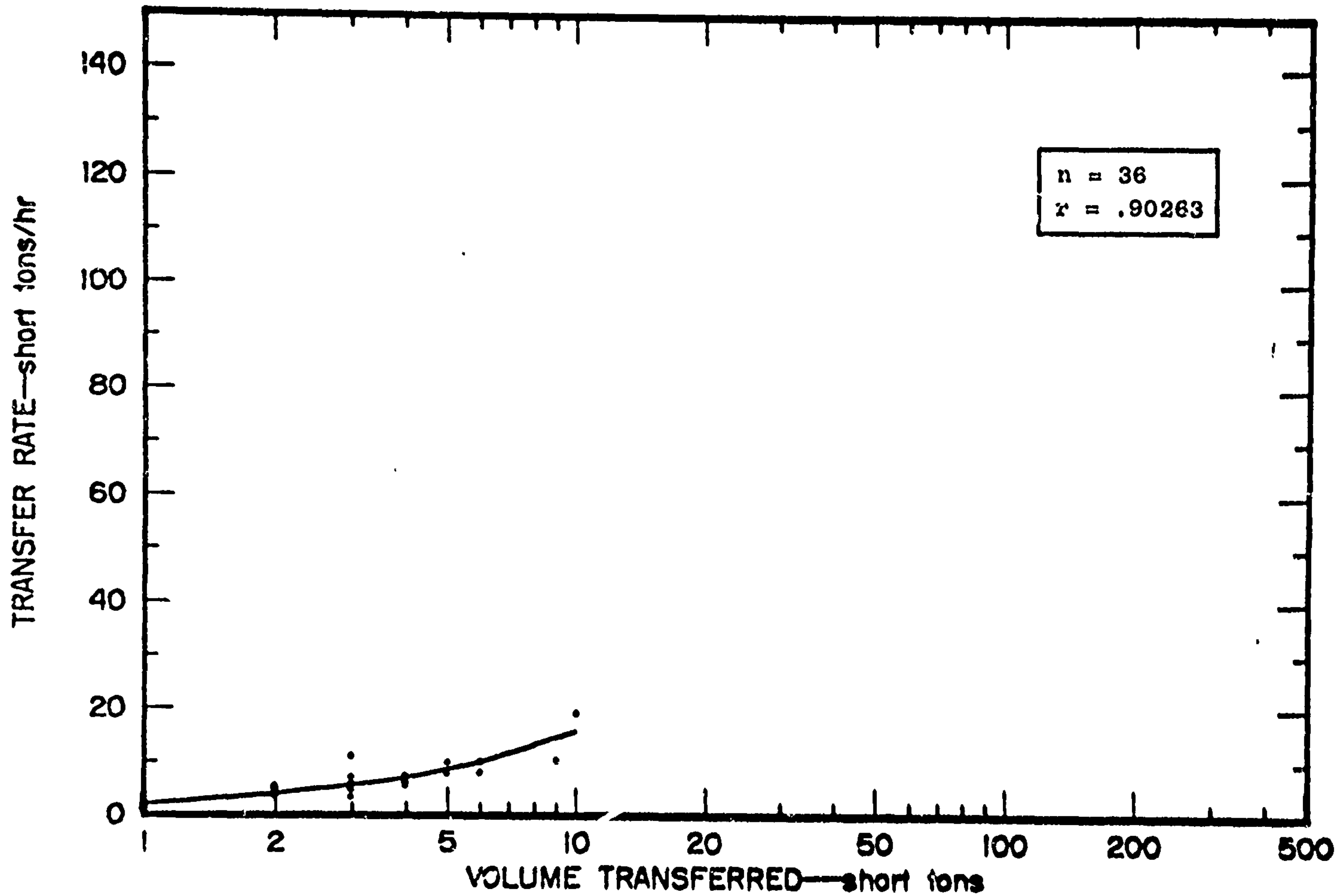


Figure A-62 TRANSFER TYPE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF DDG TYPE

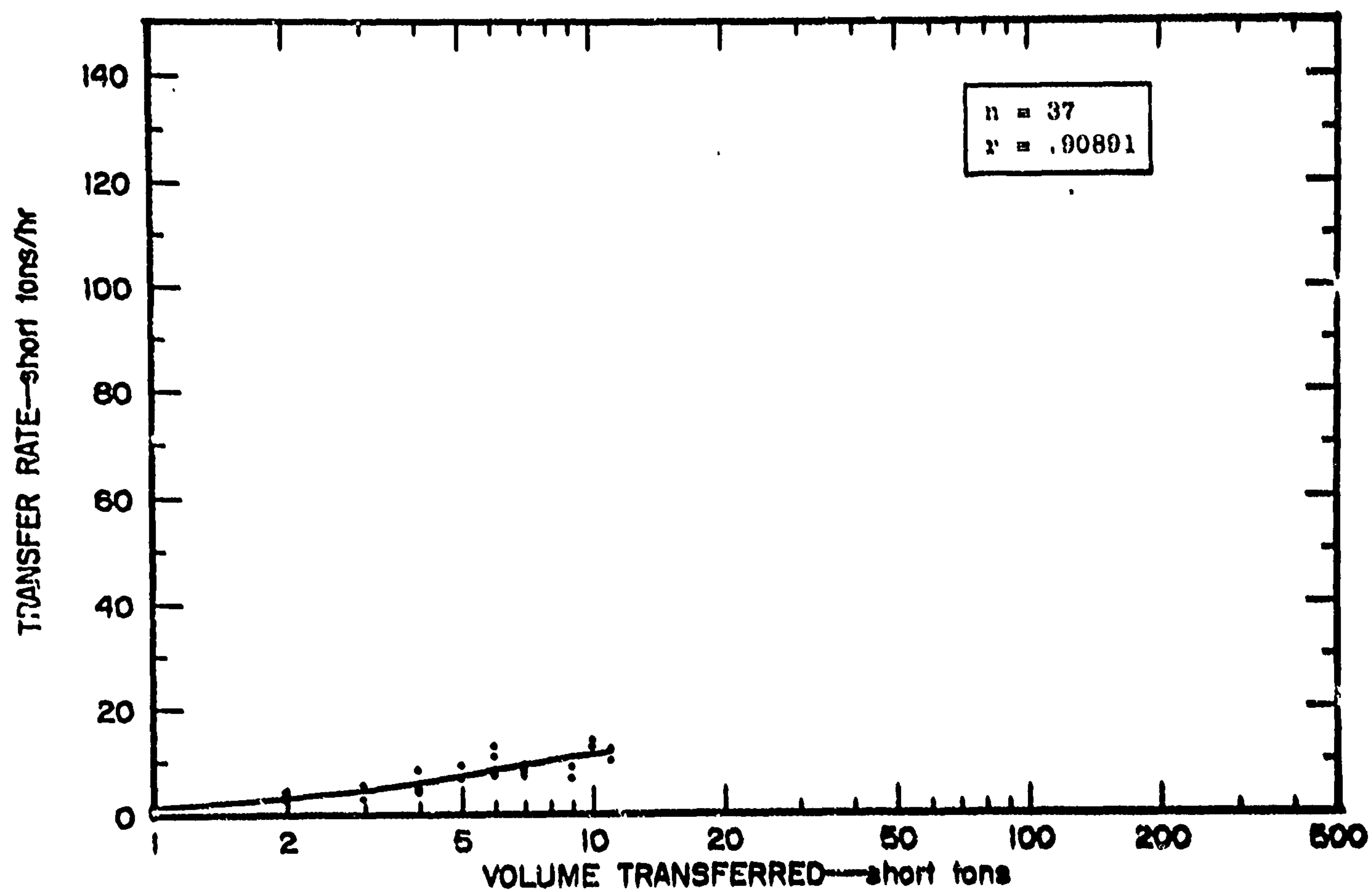


Figure A-63 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF DL, DLG AND DLGN TYPES

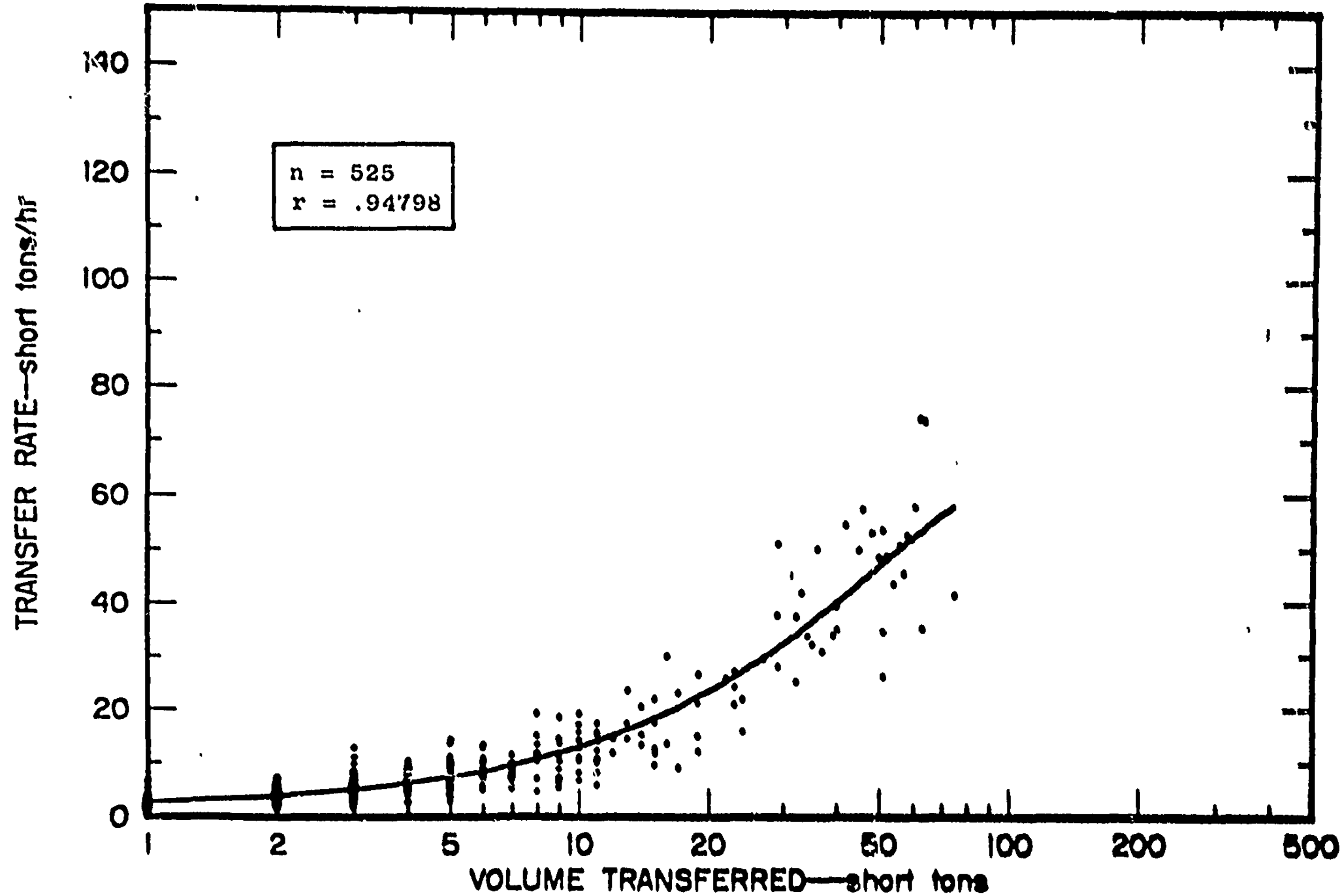


Figure A-64 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS BY AKS TYPE

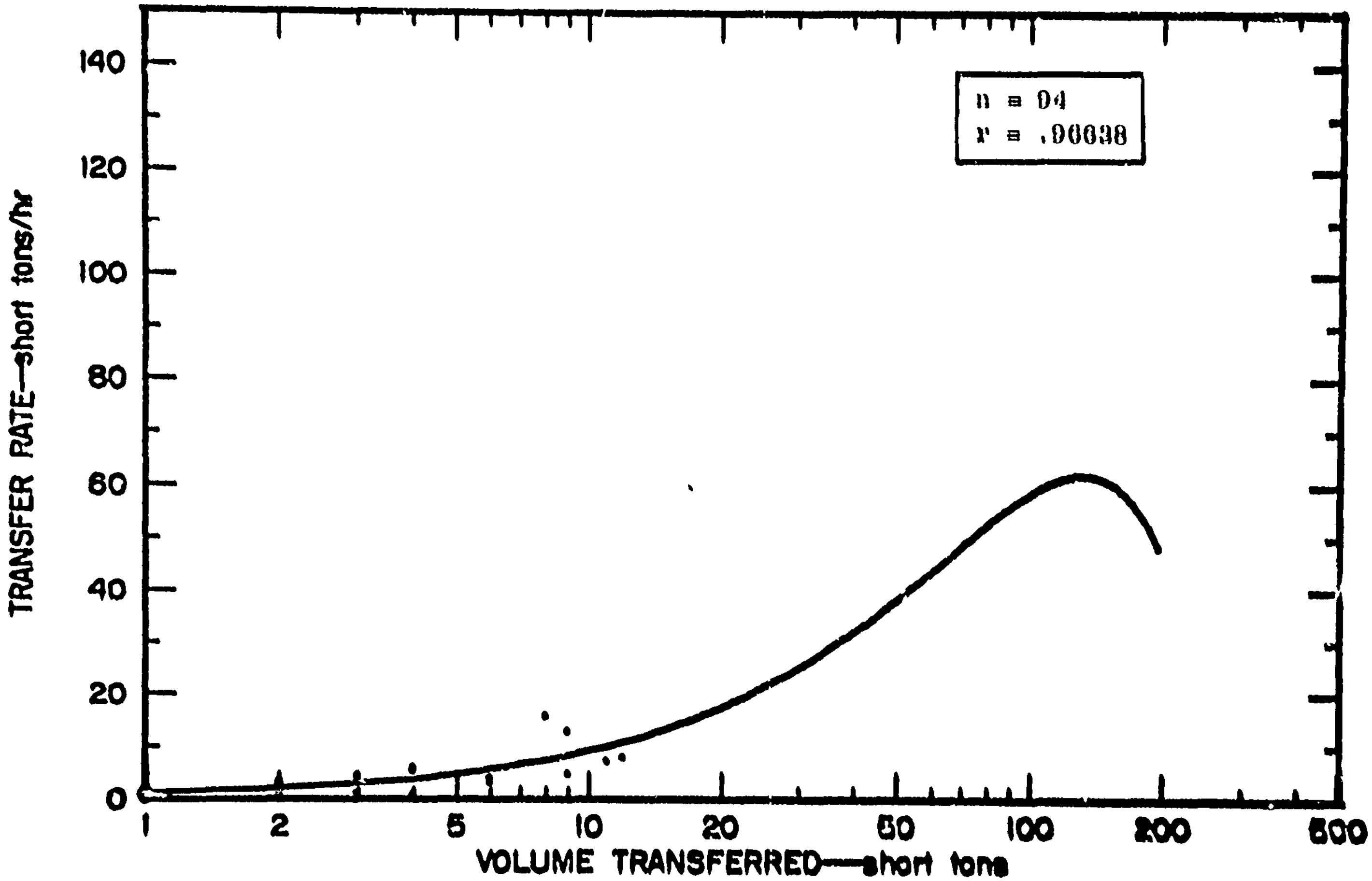


Figure A-65 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS BY AOE TYPE

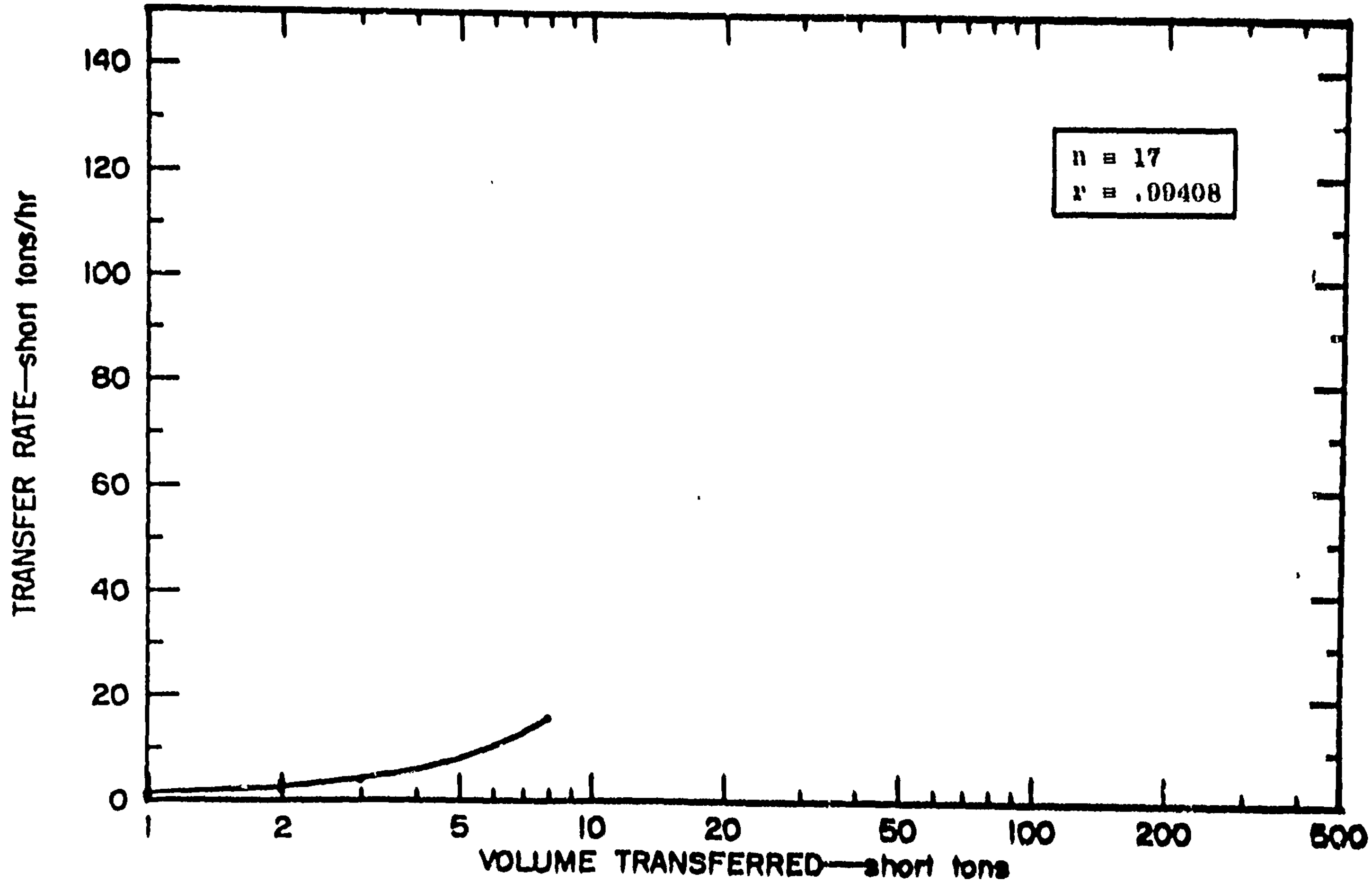


Figure A-66 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR STORES REPLENISHMENTS OF DD FRAM MK II CLASS BY AOE TYPE

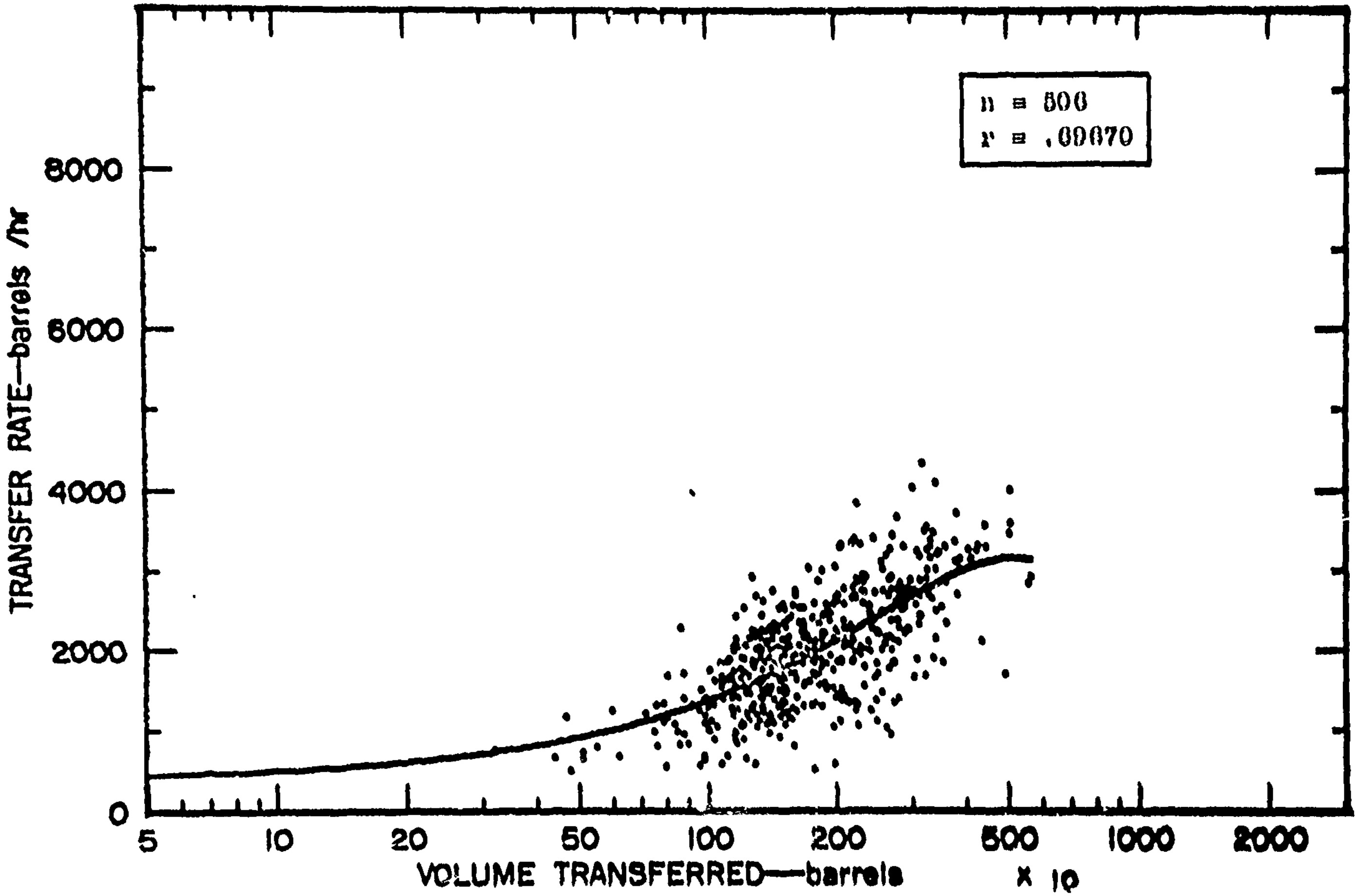


Figure A-67 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF DL, DLG AND DLGN TYPES

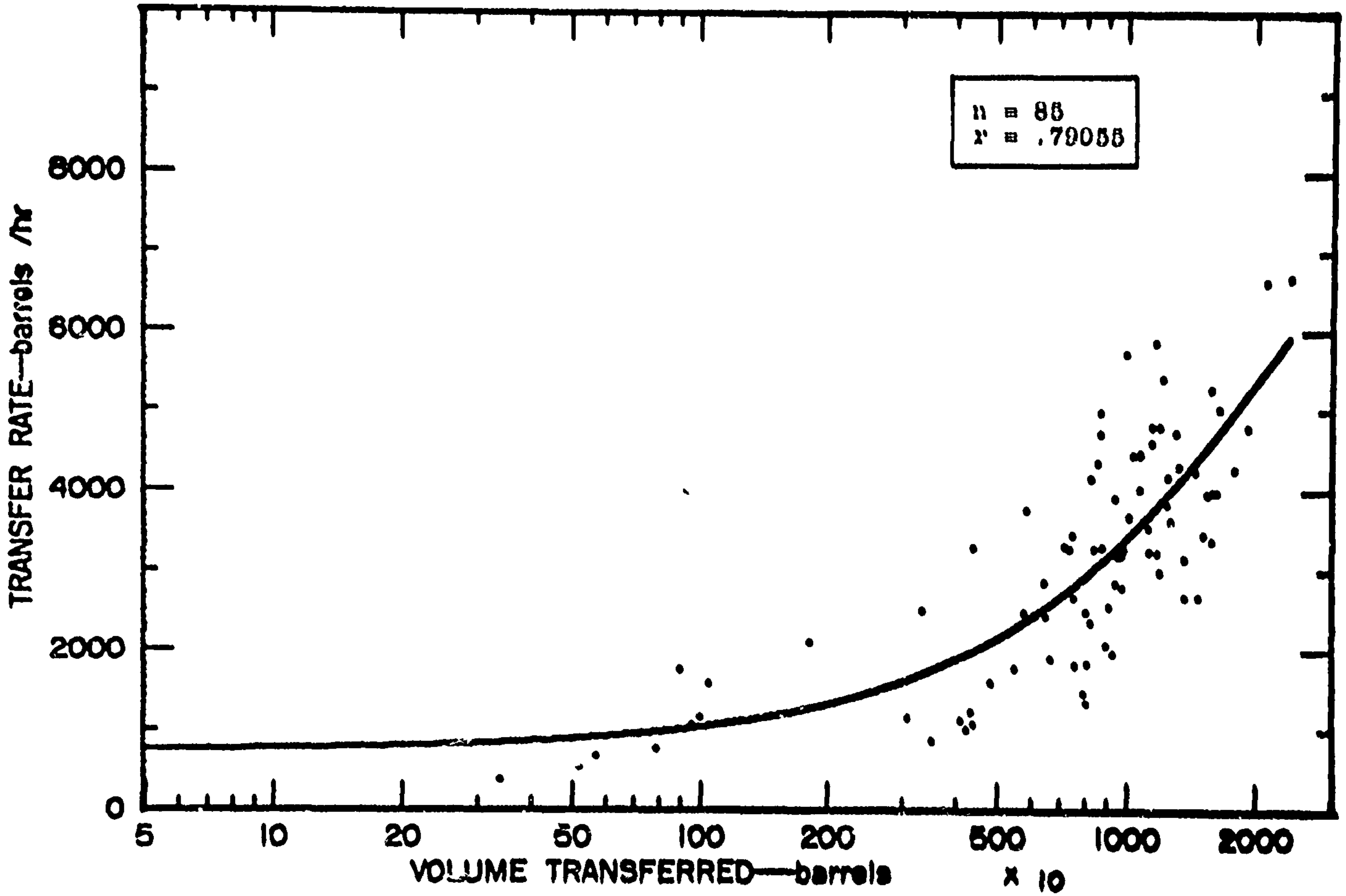


Figure A-68 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR JP REPLENISHMENTS BY AOE TYPE

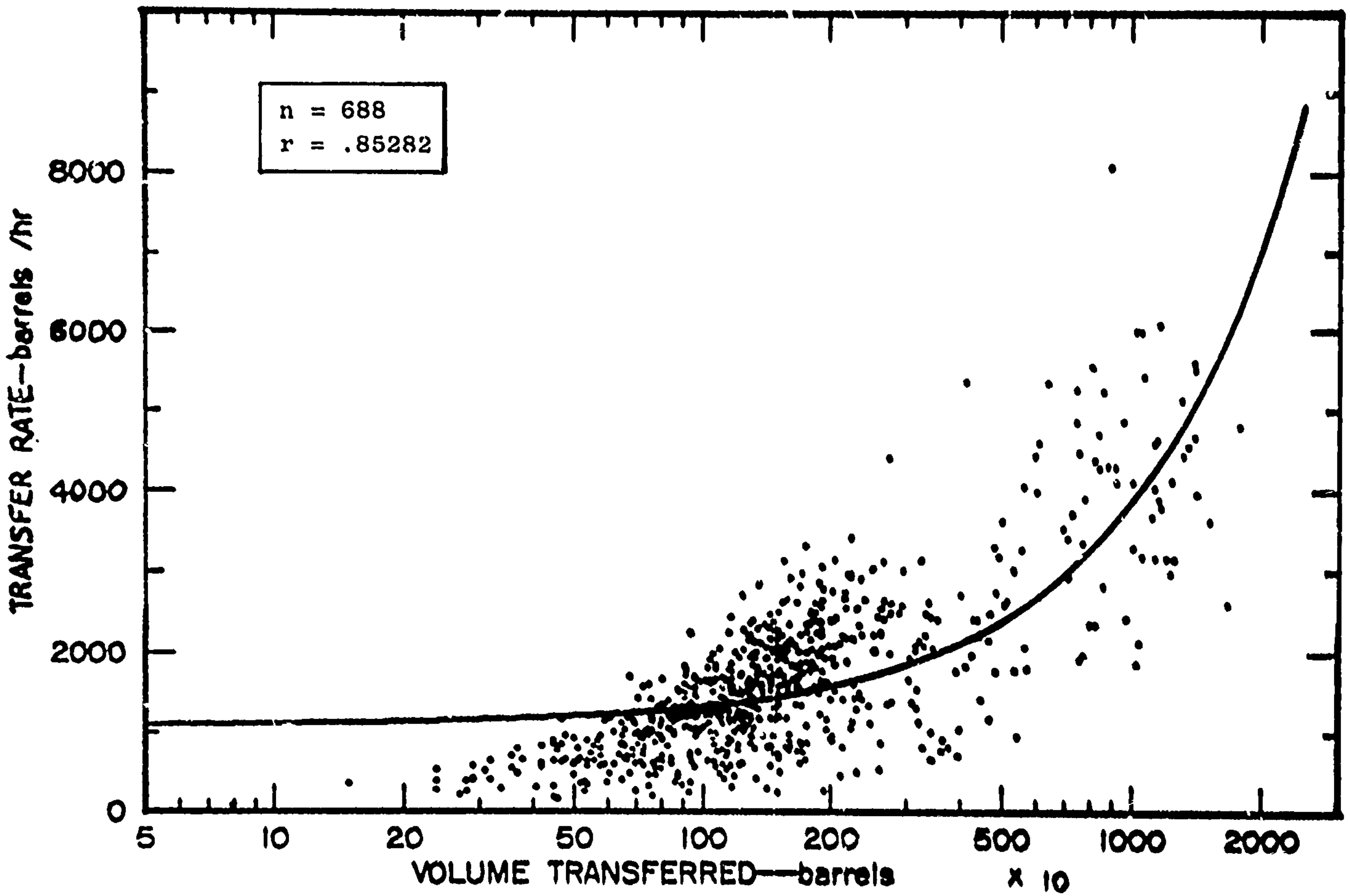


Figure A-69 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS BY AOE TYPE

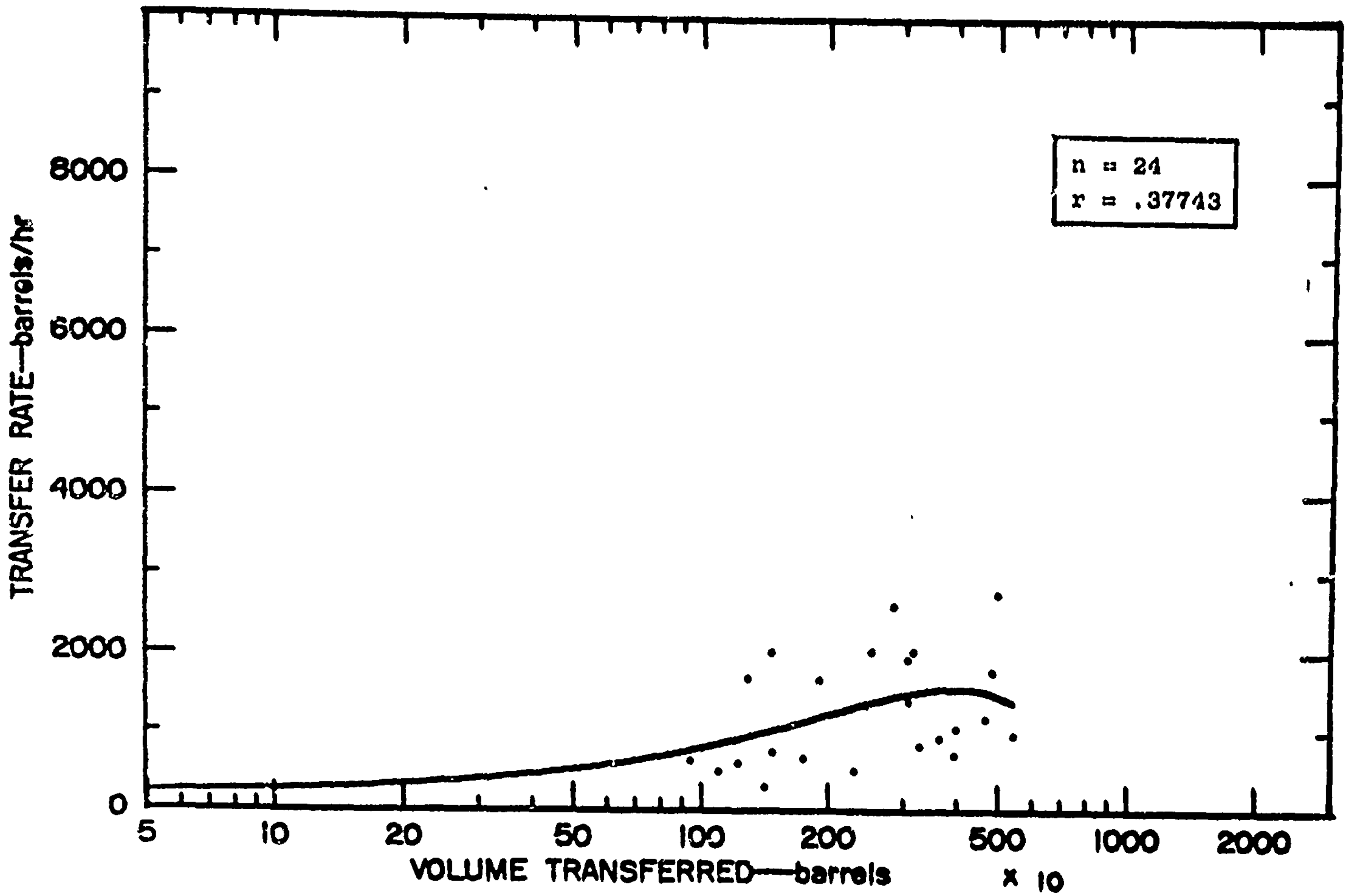


Figure A-70 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF CA, CAG AND CLG TYPES BY AOE TYPE

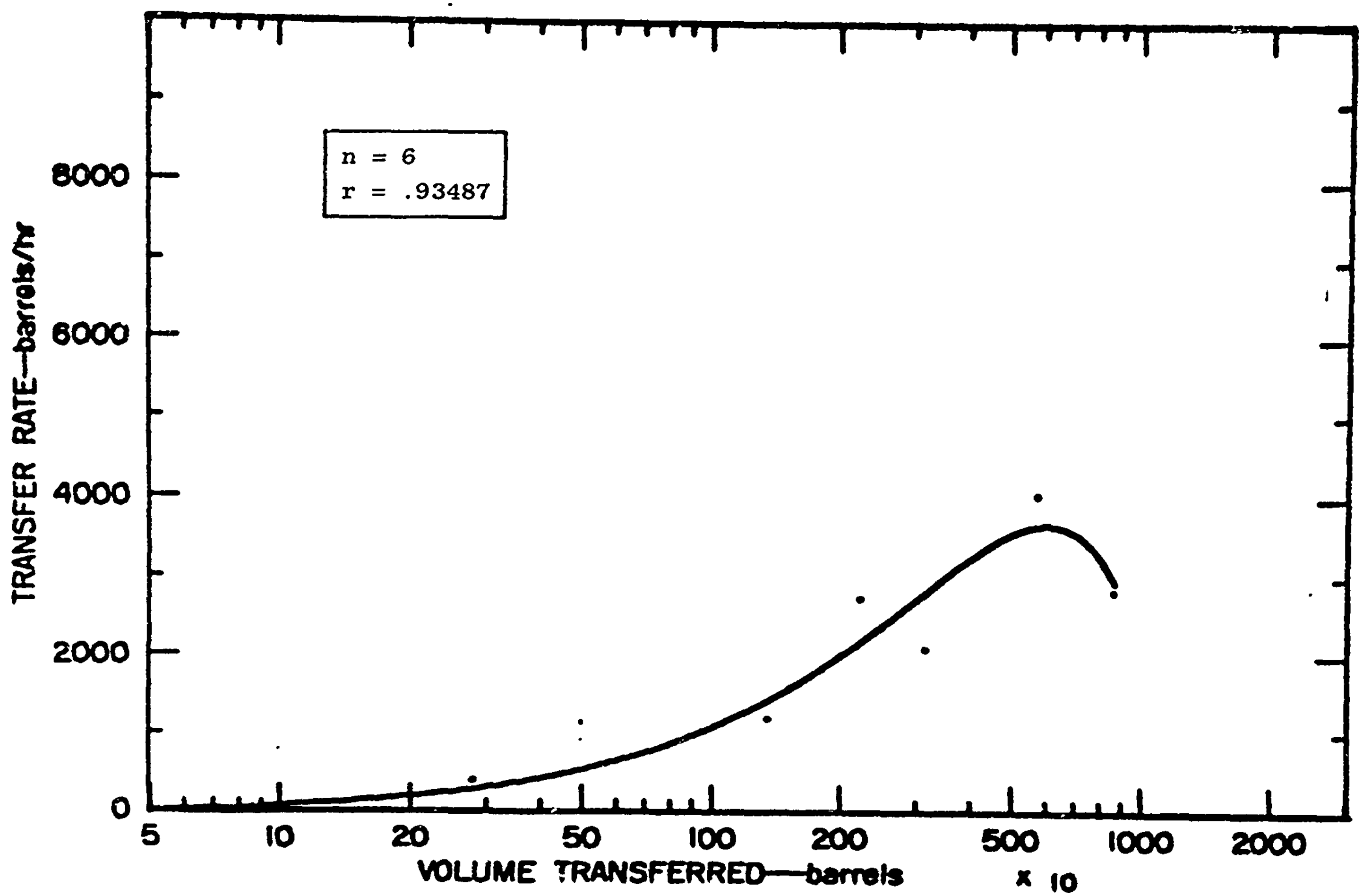


Figure A-71 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF CG AND CGN TYPES BY AOE TYPE

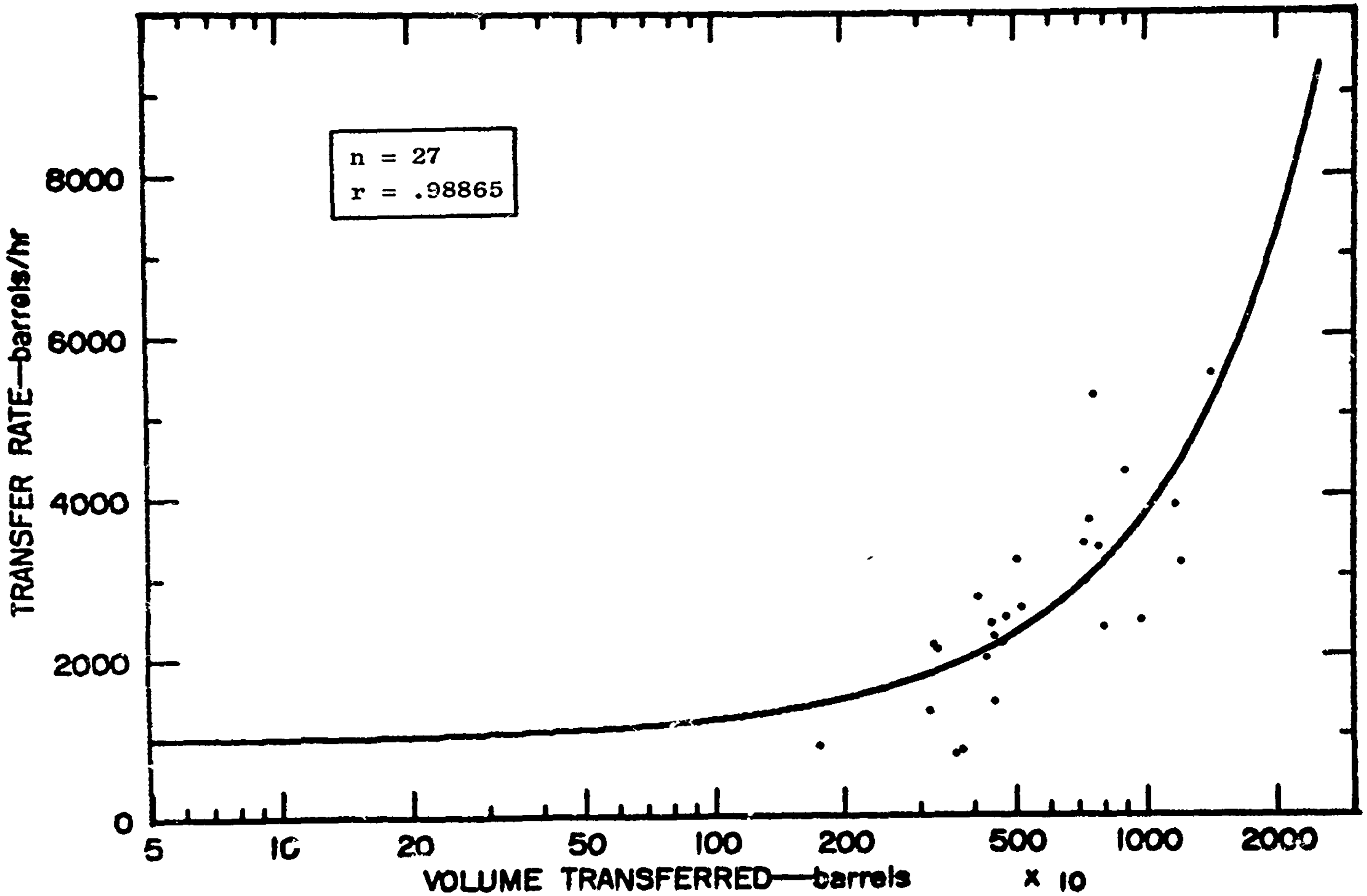


Figure A-72 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF CVA 14, 19, 31 AND 34 BY AOE TYPE

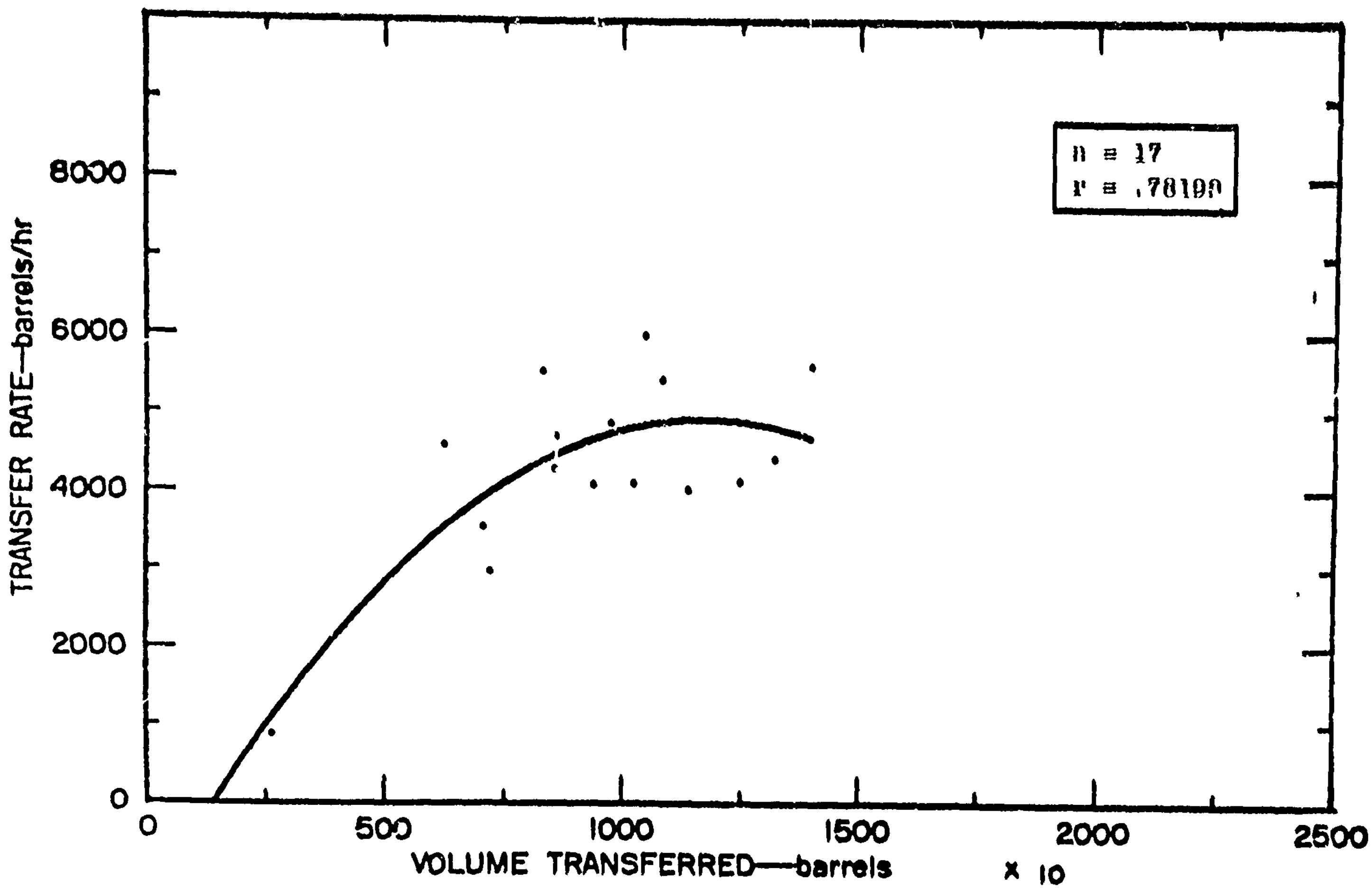


Figure A-73 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF CVA 41-43 BY AOE TYPE

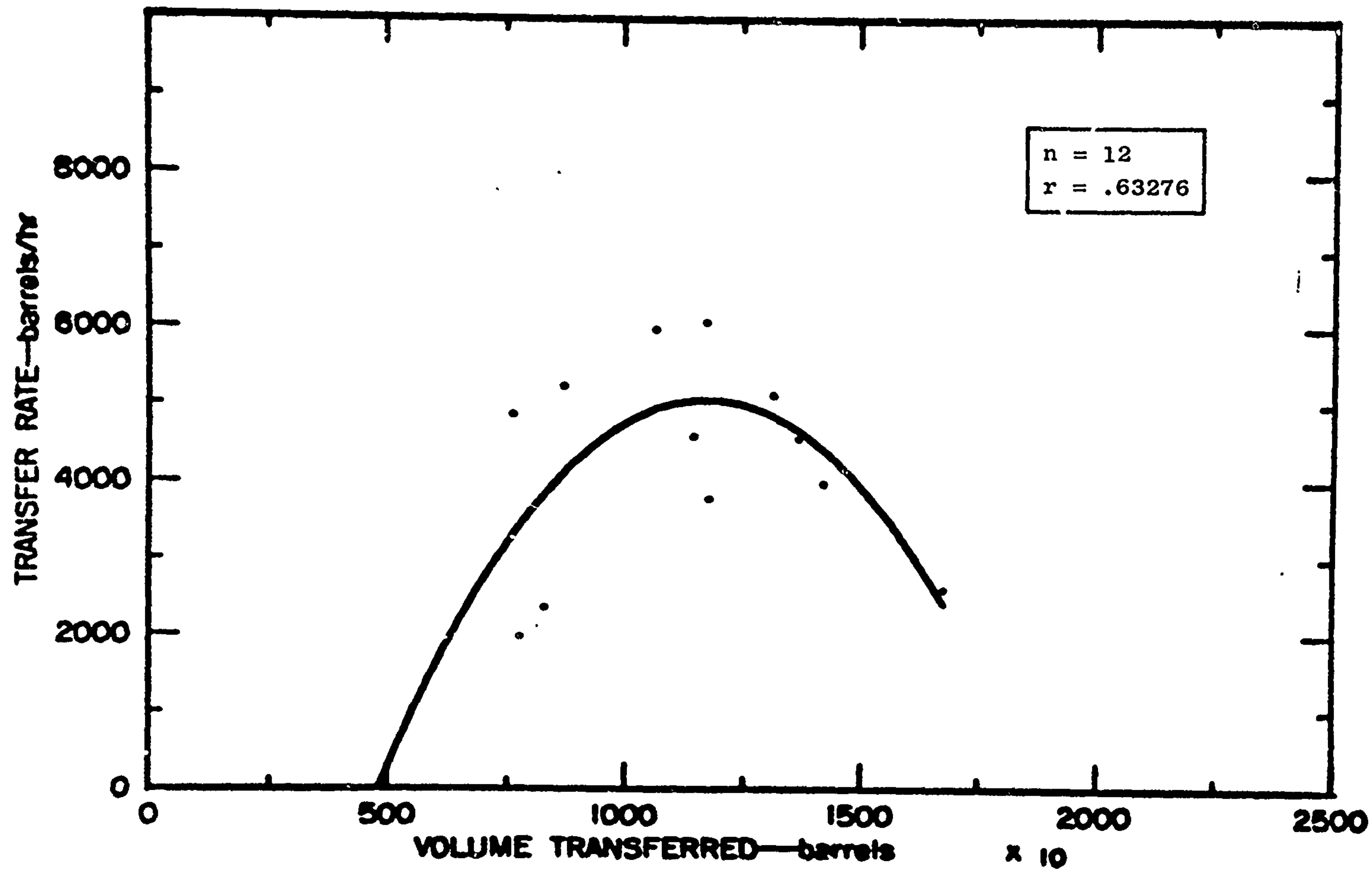


Figure A-74 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF CVA 59-62 BY AOE TYPE

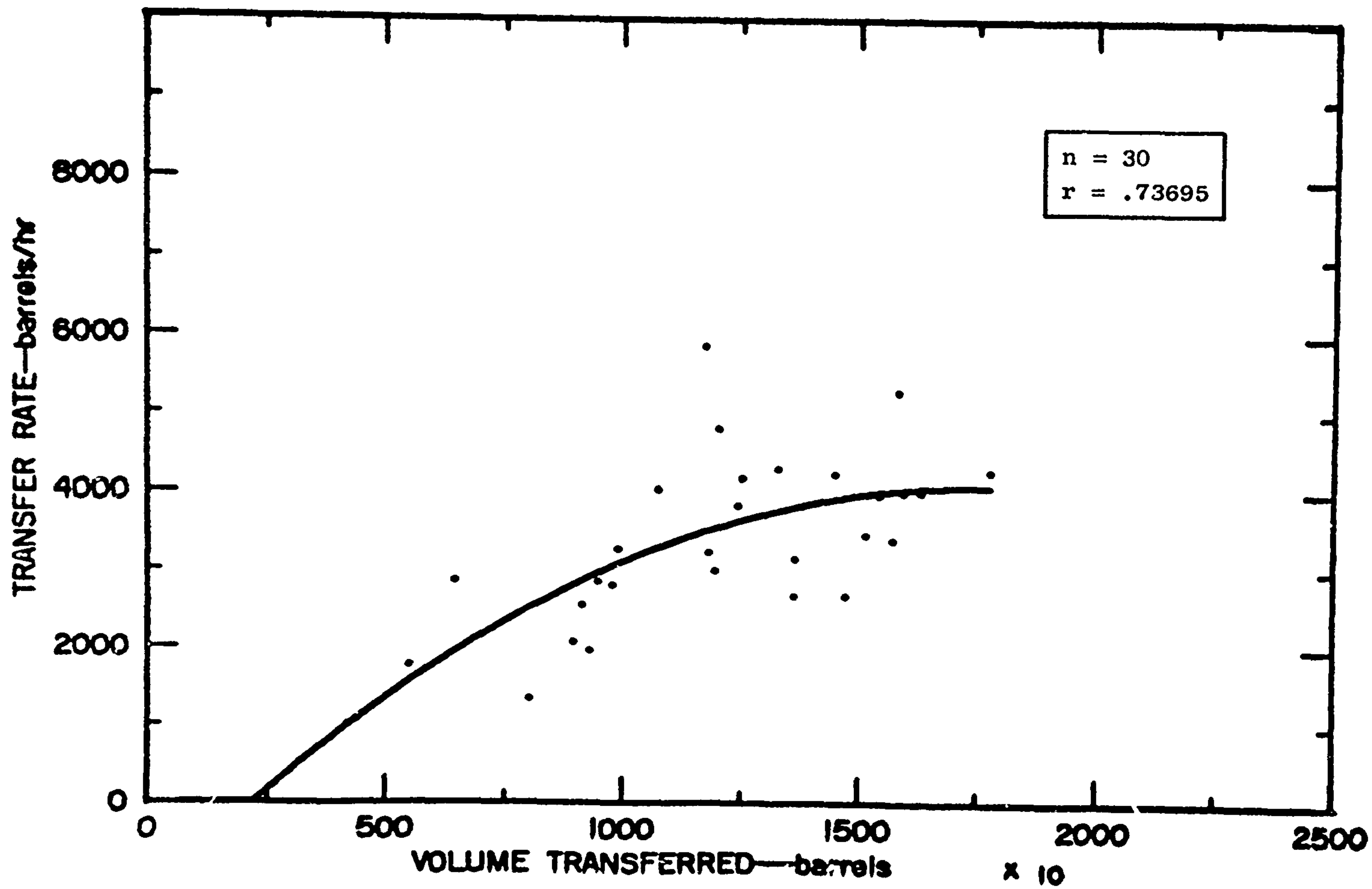


Figure A-75 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF CVA 63, 64 AND 66 BY AOE TYPE

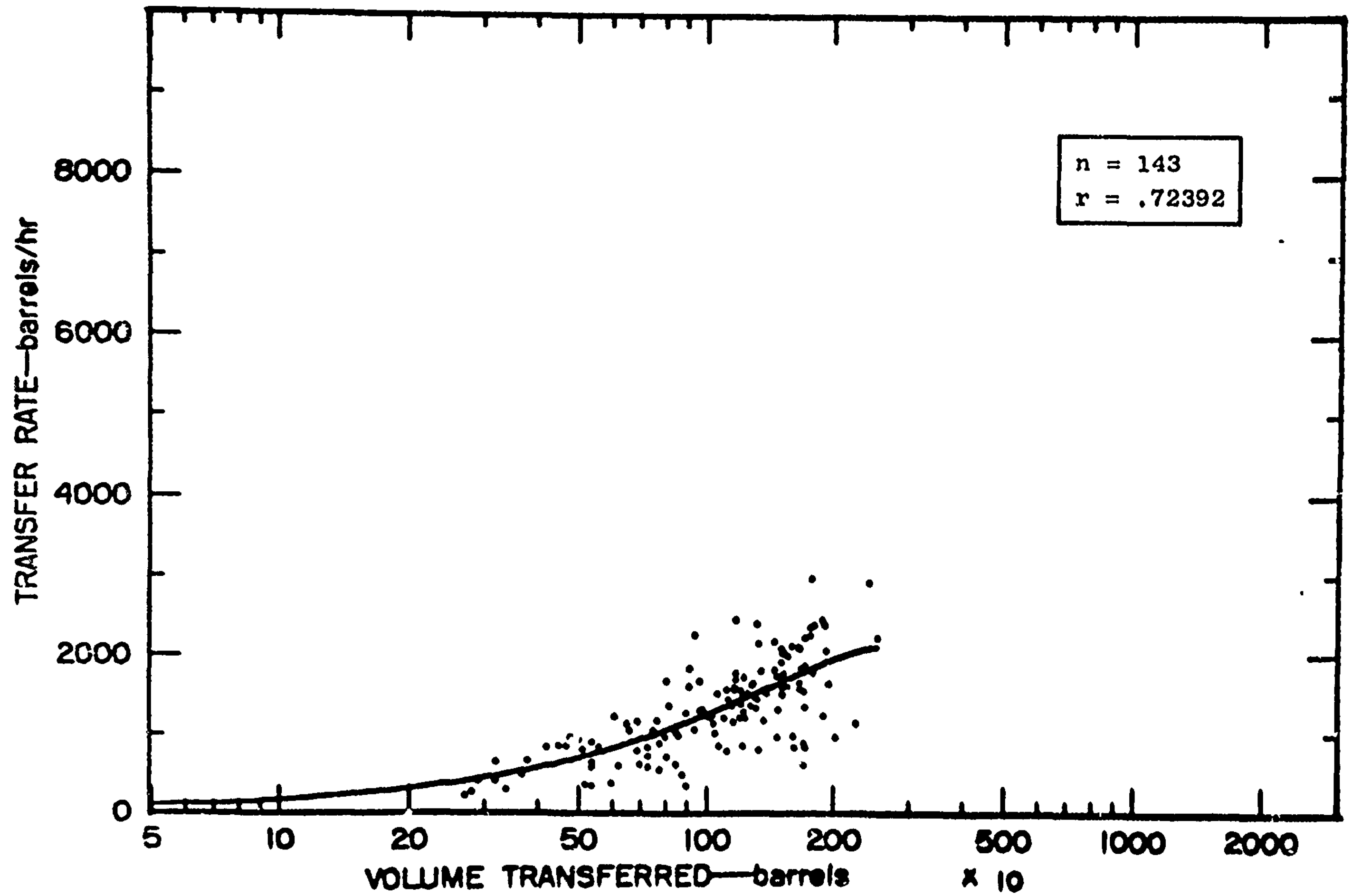


Figure A-76 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF DD CLASSES OTHER THAN FRAM MK I, FRAM MK II, 931 AND 945 BY AOE TYPE

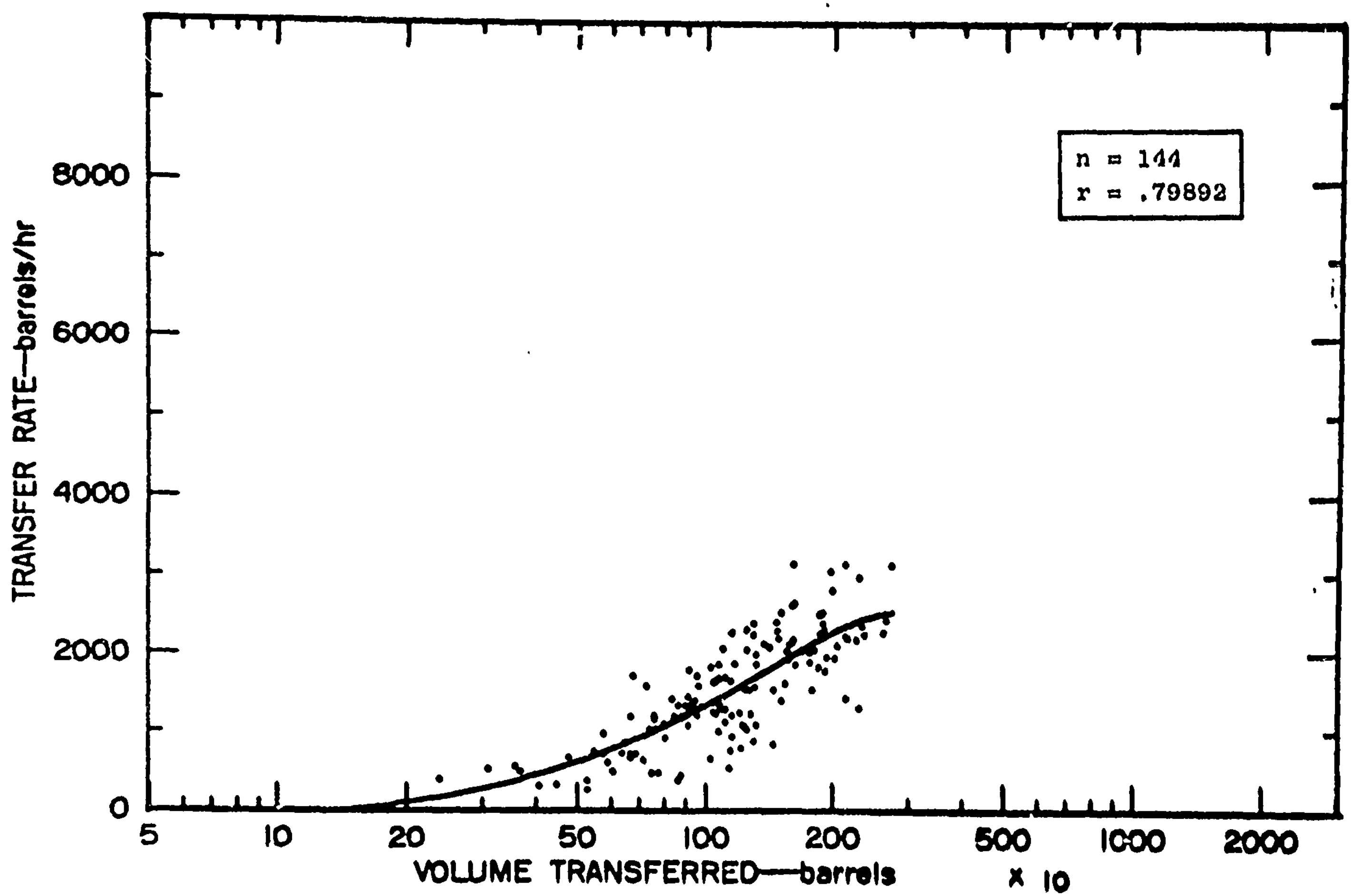


Figure A-77 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF DD FRAM MK I CLASS BY AOE TYPE

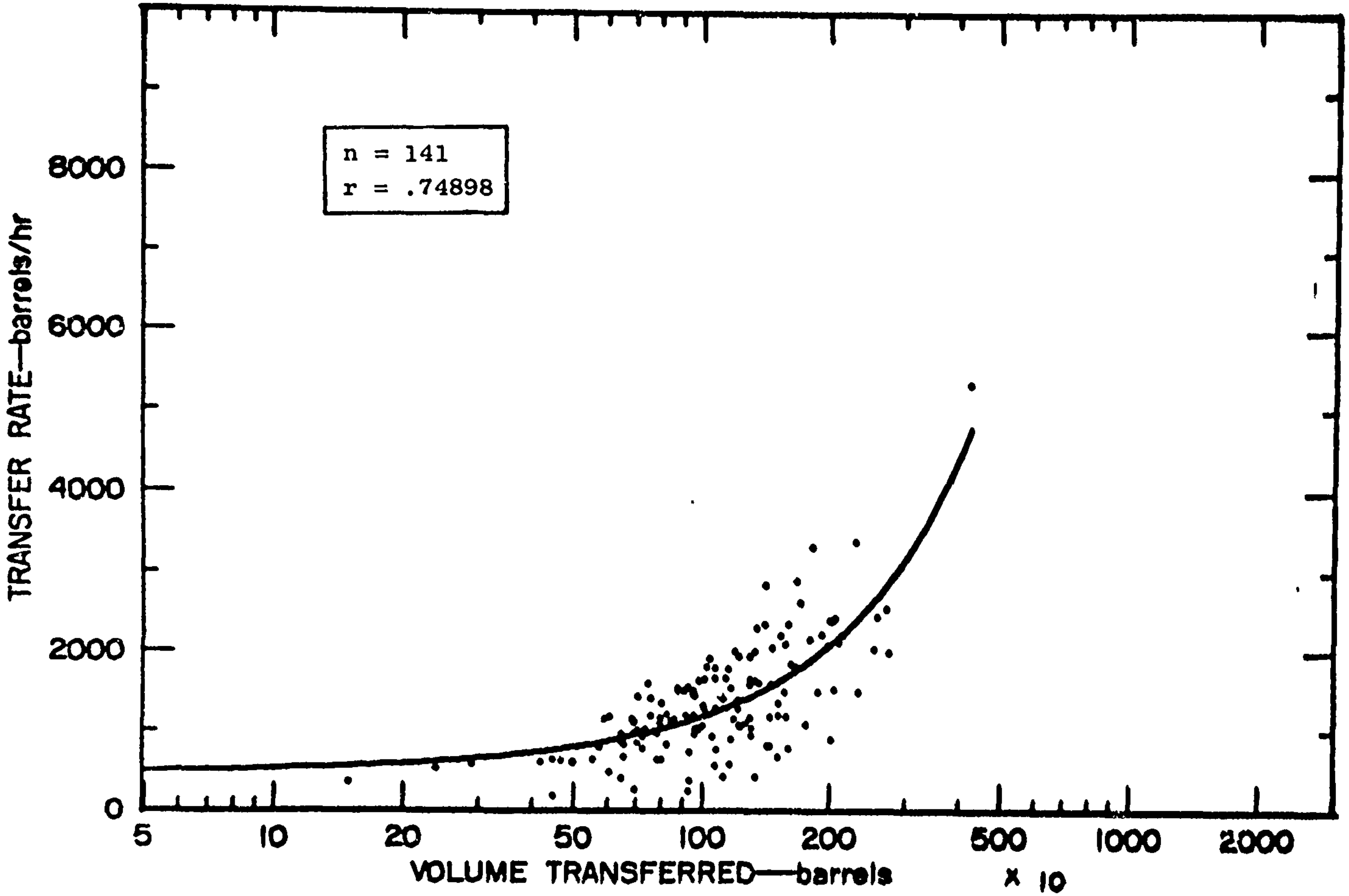


Figure A-78 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF DD FRAM MK II CLASS BY AOE TYPE

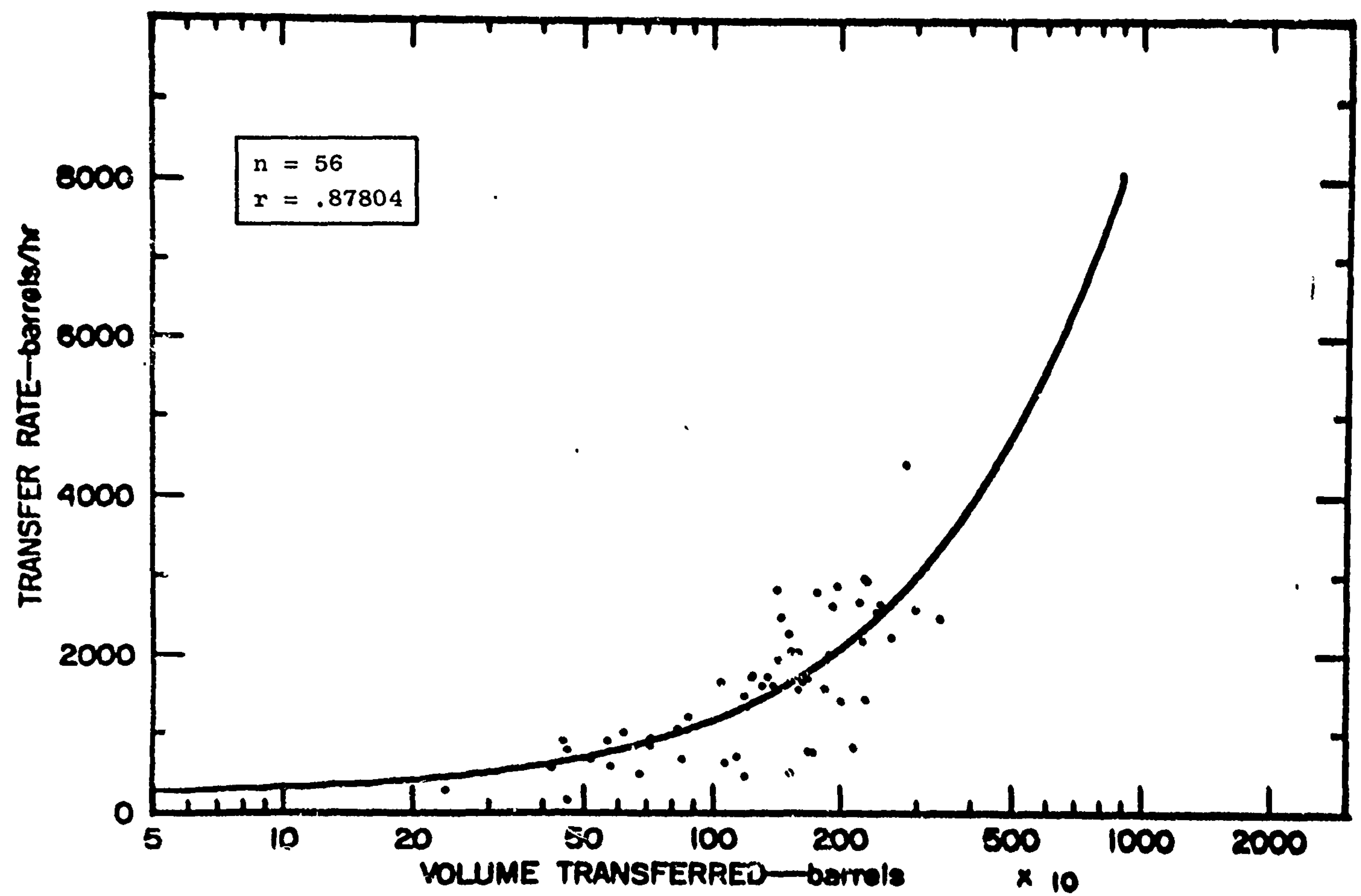


Figure A-79 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF DDG TYPE BY AOE TYPE

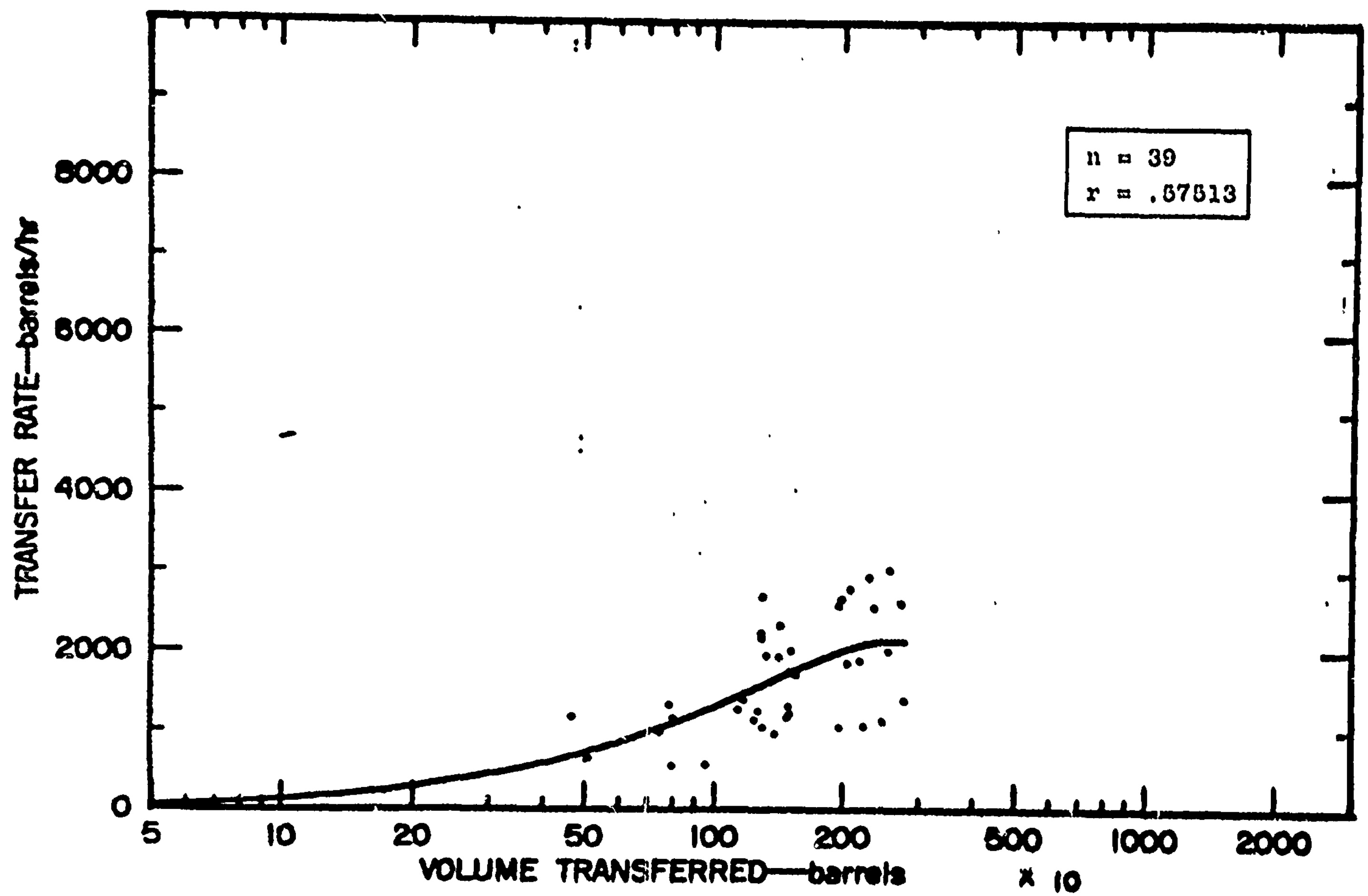


Figure A-80 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR NSFO REPLENISHMENTS OF DL, DLG AND DLGN TYPES BY AOE TYPE

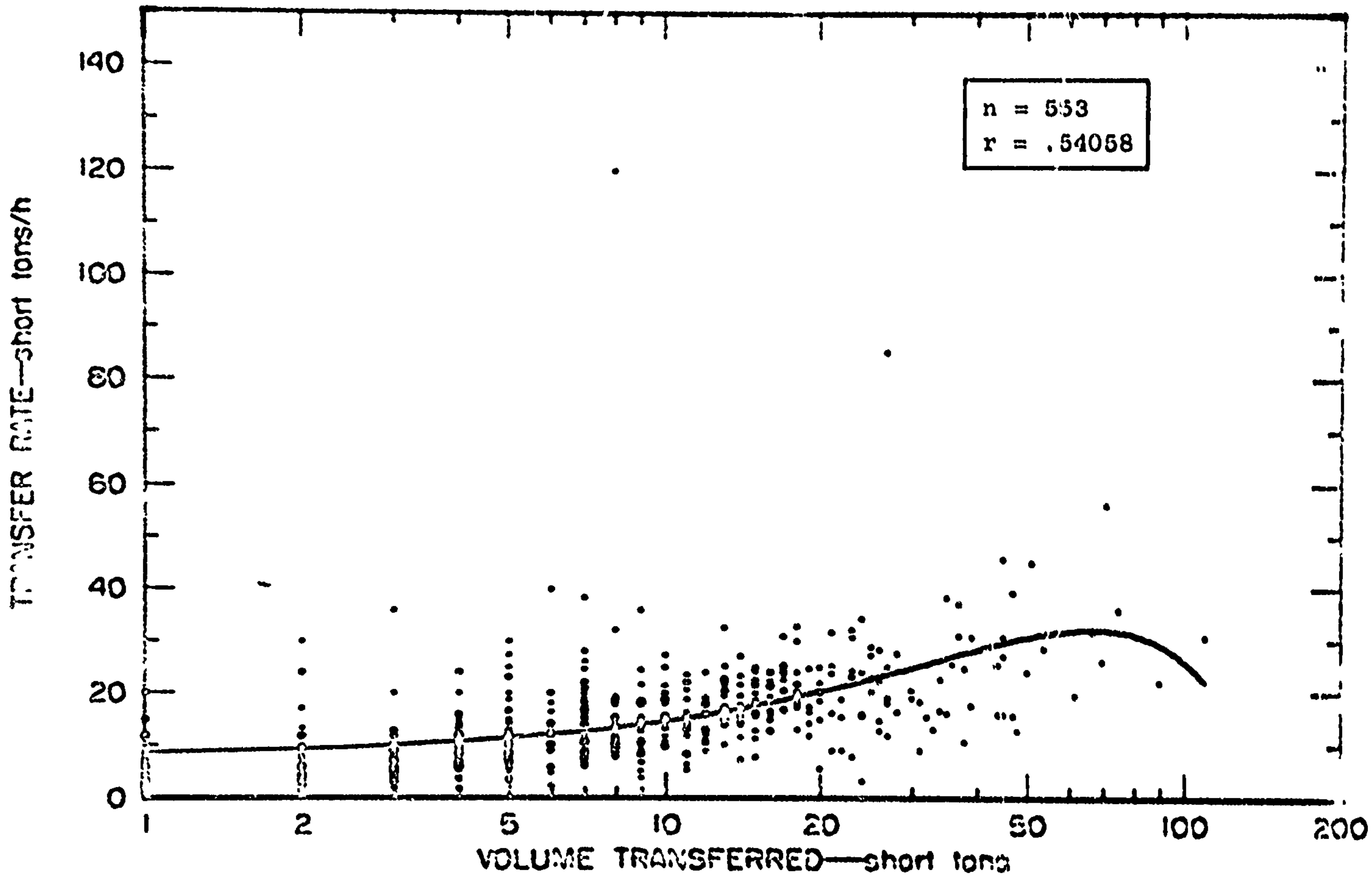


Figure A-81 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR VERTICAL REPLENISHMENTS FROM AFS TYPES

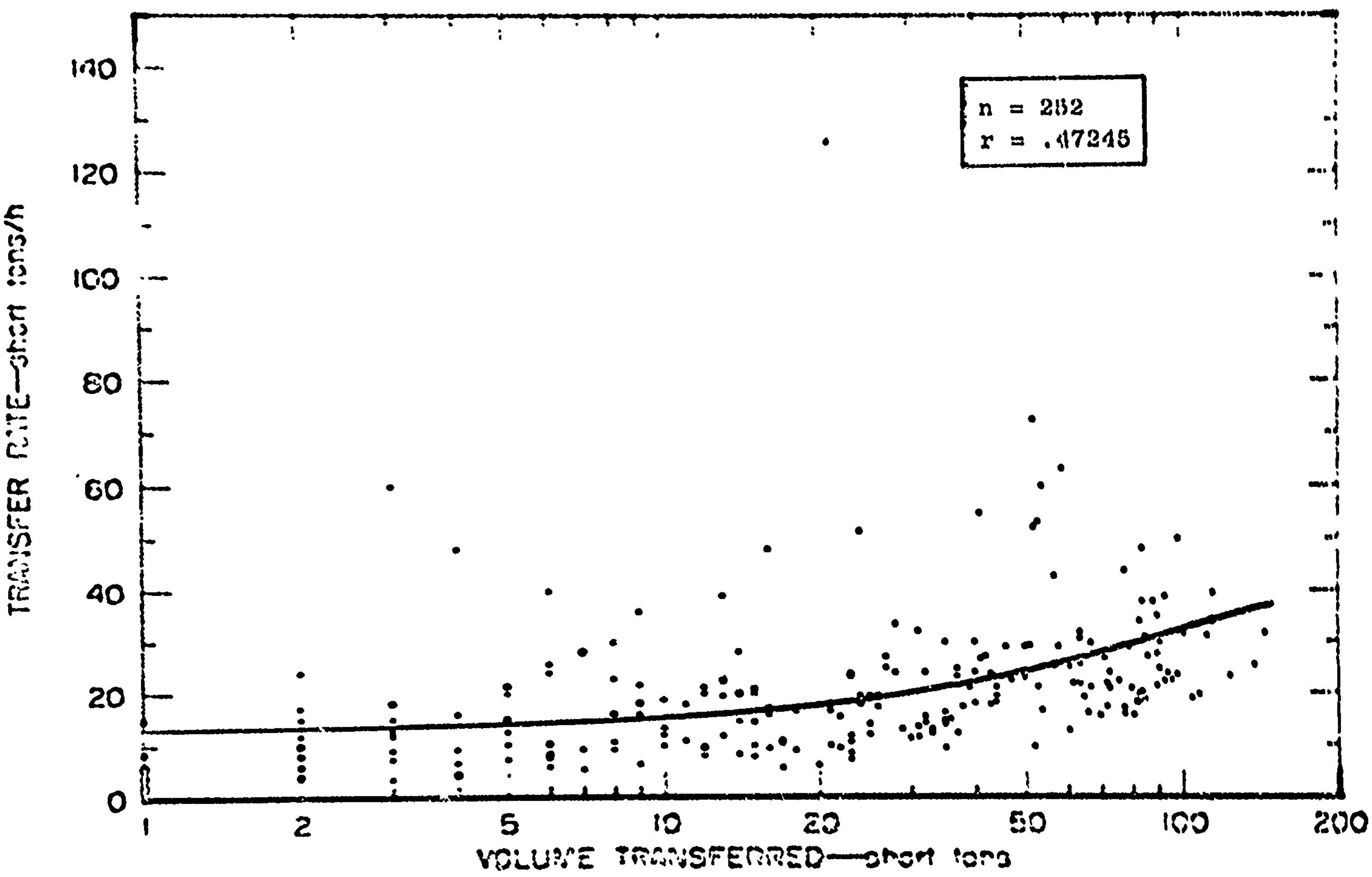


Figure A-82 TRANSFER RATE VERSUS QUANTITY TRANSFERRED FOR VERTICAL REPLENISHMENTS FROM AOE TYPES